CHAPTER 2a

Avifauna

CHAPTER 2a: Avifauna

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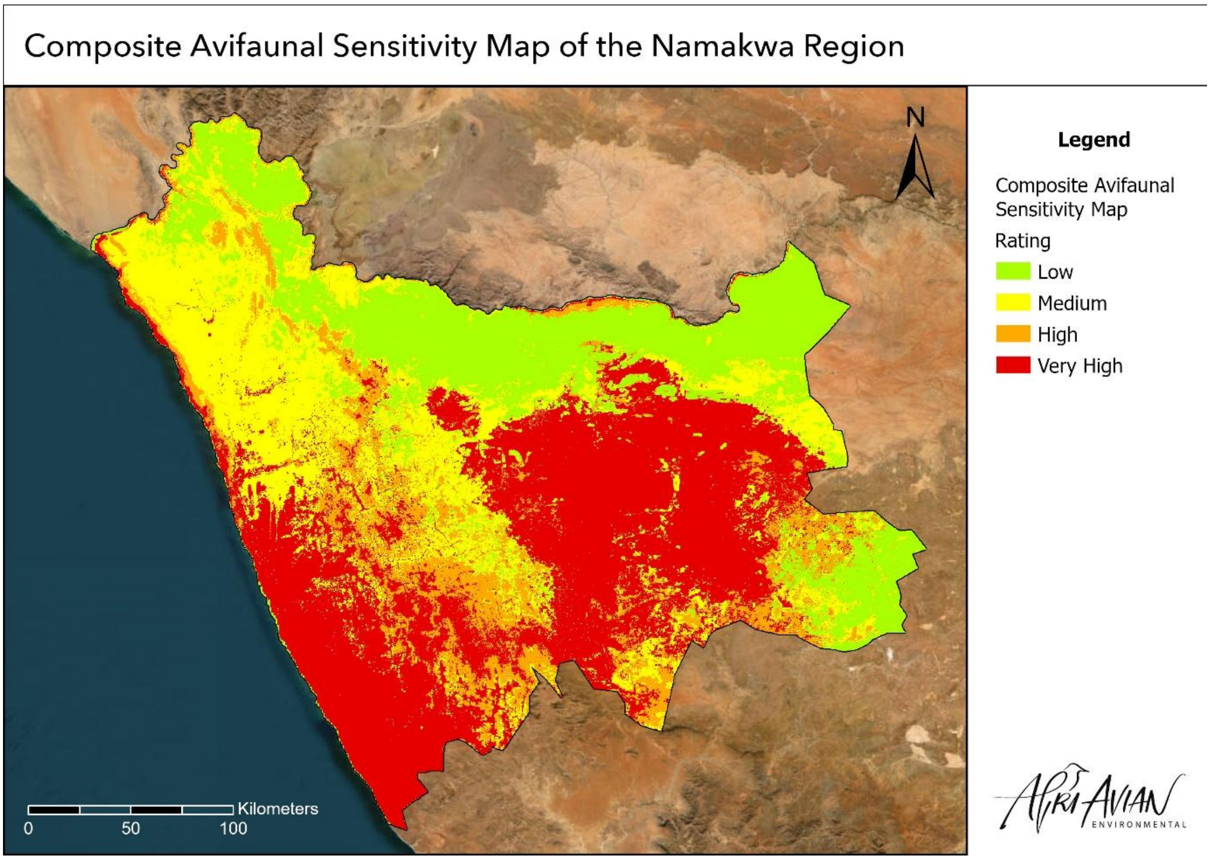
Executive Summary

This Avifaunal Specialist Assessment forms part of the Strategic Environmental Assessment (SEA) for the proposed Boegoebaai Port, Special Economic Zone (SEZ), and associated Green Hydrogen (GH_2) developments in the Northern Cape Province of South Africa. Work Package 2 (WP2) evaluates potential impacts on avifauna across the Namakwa Region, covering the Richtersveld, Nama Khoi, Kamiesberg, and Khai-Ma local municipalities, under three development scenarios:

- **Scenario 0:** Dynamic Baseline (no GH_2 development, 2023–2050)
- **Scenario 1:** "Small GH_2" (5 GW electrolyser, 0.5 Mtpa GH_2 by 2030)
- **Scenario 2:** "Big GH_2" (40 GW electrolyser, 4 Mtpa GH_2 by 2050)

The study integrates multi-year bird atlas data, species distribution modelling, habitat mapping, and a weighted risk assessment for 44 priority avifaunal species—comprising threatened, endemic, and range-restricted bird species.

The Namakwa Region lies largely within the Succulent Karoo Biodiversity Hotspot, hosting 15 Key Biodiversity Areas (KBAs) and several protected areas. Habitats range from coastal duneveld and estuarine wetlands to arid shrublands and mountain scrub, supporting species of global and national conservation concern such as Black Harrier (EN), Ludwig's Bustard (EN), Martial Eagle (EN), and Red Lark (VU, endemic). The DFFE Screening Tool classifies much of the region as of Very High avian sensitivity, particularly for wind-related impacts. The figure below shows avifaunal sensitivity of the Namakwa Region as it relates to impacts posed by renewable energy-related, including linear infrastructure in support of the various GH_2 development scenarios.



Interpretation of the Avifaunal Sensitivity Maps:

Five avifaunal sensitivity maps were produced to reflect the relative ecological sensitivity of the landscape to these potential impact pathways. Each map is derived from species distribution models weighted by species-specific vulnerability scores (threat status, range size, endemism, and susceptibility to each impact type). These maps represent potential risk or relative sensitivity to renewable energy–related infrastructure rather than fixed exclusion or “no-go” zones. They are intended as a strategic-level planning tool to guide early screening, highlight areas warranting increased caution and preconstruction monitoring, and inform project-level environmental impact assessments (EIAs). Final delineation of any formal avoidance or exclusion areas must occur during site-specific EIAs, informed by local surveys and observer effort.

Key impact pathways relating to priority avifauna include:

- **Displacement due to Disturbance** – Noise, lighting, and human activity during construction and operation.

- **Habitat Loss / Fragmentation / Transformation** – Port, SEZ, renewable energy and linear infrastructure footprints.

- **Collisions** – Wind turbines, powerlines, masts, and other tall structures.

- **Electrocutions** – Transmission and distribution infrastructure, particularly affecting large raptors and vultures.

Key findings concluded from this avifaunal risk assessment are:

- **Without mitigation**, both GH_2 development scenarios present **High to Very High** risks to priority avifaunal species, especially in areas of **Very High Sensitivity**.

- **Scenario 2 (“Big GH_2”)** carries the greatest cumulative risk, with potentially severe to extreme consequences for Endangered and Critically Endangered bird species.

- **With implementation of best-practice mitigation**, risks can be reduced to **Moderate–High**, but residual impacts remain considerable in sensitive habitats.

Even the baseline scenario reflects ongoing pressures as a result of climate change, mining, agriculture, and existing renewable energy expansion.

In conclusion, the Namakwa Region’s exceptional avifaunal diversity faces substantial risk from large scale GH_2 and associated infrastructure development given the scale of the proposed infrastructure required. Strategic avoidance of high and very high sensitivity areas, rigorous application of the mitigation hierarchy, and the implementation of robust monitoring frameworks are essential to balance renewable energy ambitions, associated with the GH_2 development proposal for the Boegoebaai Port and SEZ, with biodiversity conservation in the broader Namakwa Region. The SEA and this avifaunal risk assessment therefore provide a defensible, spatially explicit framework to guide sustainable regional planning for development and safeguarding irreplaceable bird populations.

Key recommended strategic management actions resulting from this avifaunal risk assessment include:

1. Spatial Planning & Sensitivity Controls

Embed avifaunal sensitivity mapping into planning tools (such as EMFs, SDFs, IDPs), designate no-go zones for critical habitats, apply science-based buffers, align infrastructure to avoid very high and high-risk areas, and cap cumulative development in sensitive landscapes.

2. Technology-Specific Standards

Adopt bird-safe design and operational mitigation measures for wind and solar infrastructure, powerlines, masts, and port/desalination facilities to ensure minimising collision, electrocution, and disturbance risks through appropriate siting, engineering, and seasonal restrictions.

3. Monitoring & Adaptive Management

Use standardised pre- and post-construction monitoring protocols with GenEst[1], set Thresholds of Potential Concern (TPCs), link results to Potential Biological Removal (PBR) rates and Population Viability Analysis (PVA), and trigger adaptive measures when thresholds are exceeded.

4. Governance & Data Management

Mandate avifaunal standards and independent oversight in approvals, require cumulative impact reviews, ensure open data sharing, and establish a regional technical forum for coordinated decision-making.

5. Incentives & Financing

Fast-track low-risk, high-standard projects and fund biodiversity actions such as retrofitting hazardous infrastructure and securing key buffer habitats through a dedicated conservation fund.

[1] A Generalized Estimator of Mortality is a free, open-source statistical model and software tool, most notably named GenEst, that is used to accurately estimate the total number of wildlife (bird) fatalities in a specific area, particularly at facilities like wind or solar farms, especially when not all mortalities are directly observed and where discovery probability is less than one (https://www.usgs.gov/software/genest-a-generalized-estimator-mortality).

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ANNEXURE A: Table detailing the species-impact scoring framework that defines the sensitivity categories underpinning the multiplicative weighting system used to enable the spatial risk mapping for this avifaunal specialist assessment

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Abbreviations

BGIS	Biodiversity Geographic Information System
BLSA	BirdLife South Africa
CR	Critically Endangered
CSIR	Council for Scientific and Industrial Research
CWAC	Coordinated Waterbird Counts
DFFE	Department of Forestry, Fisheries and the Environment
E	Endemic
ECO	Environmental Control Officer
EIA	Environmental Impact Assessment
EMF	Environmental Management Framework
EMPr	Environmental Management Programme
EN	Endangered
EWT	Endangered Wildlife Trust
GenEst	Generalized Estimator of Mortality
GH_2	Green Hydrogen
GPS	Global Positioning System
GW	Gigawatt
IBA	Important Bird Area
IDP	Integrated Development Plan
IUCN	International Union for the Conservation of Nature
KBA	Key Biodiversity Area
kV	Kilovolt
LC	Least Concern
Mtpa	Million Tonnes Per Annum
MW	Megawatt
NA	Not Endemic
NCEDA	Northern Cape Economic Development Trade and Investment Promotion Agency
NE	Near Endemic
NGO	Non-Governmental Organization
NPAES	National Protected Area Expansion Strategy
NT	Near Threatened
OHL	Overhead Powerline
PAOI	Proposed Area of Impact
PBR	Potential Biological Removal
PSC	Project Steering Committee

PVA	Population Viability Analysis
PV	Photovoltaic
SABAP1	First Southern African Bird Atlas Project
SABAP2	Second Southern African Bird Atlas Project
SANBI	South African Biodiversity Institute
SANEDI	South African National Energy Development Institute
SANParks	South African National Parks
SCC	Species of Conservation Concern
SDF	Spatial Development Framework
SDM	Species Distribution Model
SEA	Strategic Environment Assessment
SEZ	Special Economic Zone
SLE	Endemic to South Africa, Lesotho and Eswatini
TNPA	Transnet National Ports Authority
TPC	Thresholds of Potential Concern
VU	Vulnerable
WEF	Wind Energy Facility
WP2	Work Package 2

1. INTRODUCTION

The Transnet National Ports Authority (TNPA) has embarked on determining the feasibility for the development, construction, and operation of a deep-water port with associated landside port facilities at Boegoebaai, Northern Cape. The proposed new port development is primarily to enable the Northern Cape's Provincial Economic Development strategy including the Green Hydrogen (GH_2) Strategy and expanding the mining and industrial base in the Northern Cape.

Green hydrogen is hydrogen gas (H_2) that is produced using renewable energy sources, typically solar or wind power, through a process called electrolysis. In this process, water (H_2O) is split into hydrogen (H_2) and oxygen (O) using an electric current, and when that electricity comes from renewable sources, the resulting hydrogen is considered "green."

Green hydrogen production, at the scale envisaged, is a diverse and multifaceted process with many direct and indirect impacts, both positive and negative. All programme components (including their interconnected transport corridors) would require vast areas of land surface, as well as other resource intensive inputs, all proposed in a sparsely populated but ecologically sensitive, arid region. Existing land uses in the study area include conservation, agriculture, fisheries, tourism, and mining.

A Strategic Environmental Assessment (SEA) has been initiated through a collaboration between the South African National Energy Development Institute (SANEDI), Northern Cape Economic Development Trade and Investment Promotion Agency (NCEDA), and the Transnet National Ports Authority (TNPA) (the Project Steering Committee (PSC)). The Council for Scientific and Industrial Research (CSIR) has been appointed to undertake this independent SEA. The overarching purpose of the SEA is to develop an integrated decision-making framework to guide the planning of the proposed Boegoebaai Port, Special Economic Zone, and wider Namakwa region in a sustainable manner.

AfriAvian Environmental has been appointed by the CSIR to conduct the SEA's avifaunal component for the proposed Boegoebaai Port and Special Economic Zone (WP1 report dated April 2025[2]) and the wider Namakwa Region (**WP2 i.e., this report**).

2. SCOPE OF THIS STRATEGIC ASSESSMENT -WORK PACKAGE 2 (WP2)

2.1 Study Area i.e., Namakwa Region

The spatial scope for the WP2 Avifaunal Assessment is delimited by four local municipalities: the Richtersveld, Nama Khoi, Kamiesberg and Khâi Ma Local Municipalities (**Figure 1**).

[2] Froneman et al. 2025. Strategic Environmental Assessment for the proposed Boegoebaai Port and Special Economic Zone: Work Package 1 – Avifaunal Specialist Assessment. AfriAvian Environmental (Pty) Ltd.

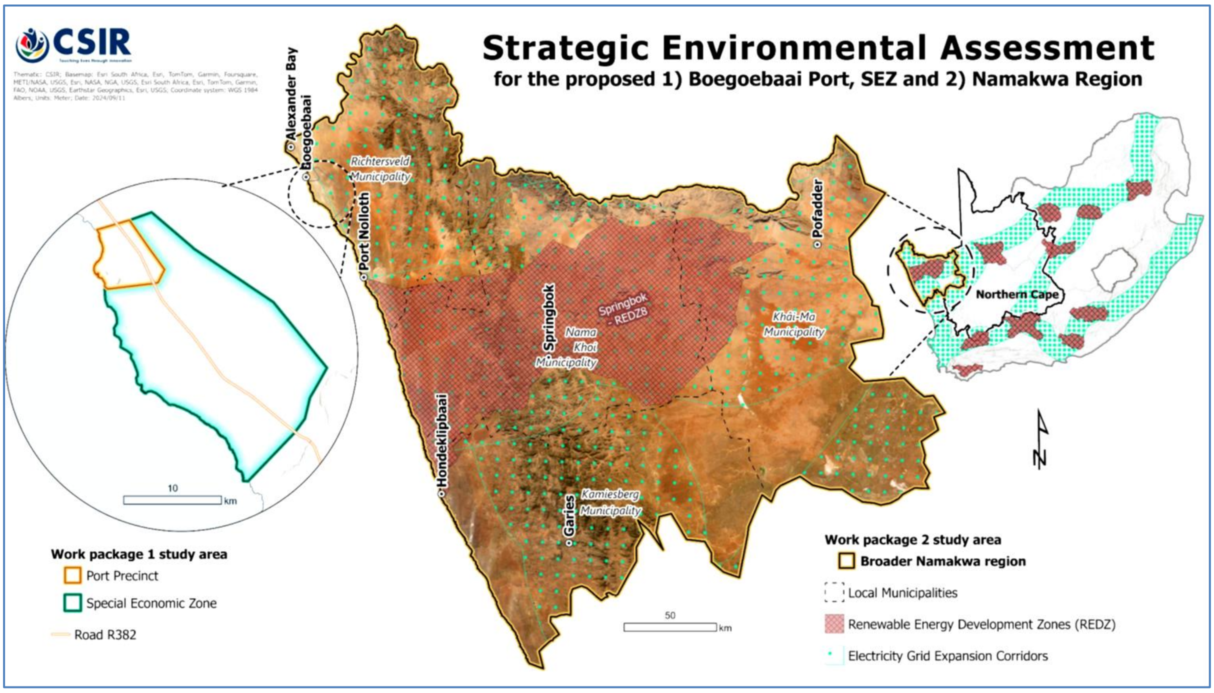

Figure 1: The spatial extent of the two SEA Work Packages with this report focusing on the Work Package 2 study area i.e., the Broader Namakwa Region (Source: CSIR, 2025).

2.2 GH_2 Development Scenarios for Assessment

Two GH_2 development scenarios will be assessed, each compared to an existing dynamic baseline, where no GH_2 development occurs but other anthropogenic and climate changes continue, and are described below:

2.2.1 SCENARIO 0 – DYNAMIC BASELINE (2023 – 2050)

The Boegoebaai Port and SEZ remains undeveloped and no GH_2 is produced in this area of the Northern Cape. The Namakwa Region's economy proceeds to be shaped by mining (i.e., diamonds, zinc, lead, copper and sand), agriculture (mainly livestock), fishing, and a growing renewable energy sector, alongside seasonal tourism linked to the Namaqualand wildflower displays. Also persisting are the current social (e.g. migration, unemployment), ecological and climatic (e.g. desertification, storm surges, coastal flooding, etc.) trends impacting on the Namakwa Region.

Contrary, conservation is being promoted as the preferred land use for the Namakwa Region, rather than mining or industrial activities that carry environmental costs. This approach is supported by landscape conservation initiatives (for example, SANParks' Mega Living Landscapes, conservation stewardships and park management), provincial strategic planning under NPAES, and Nature Reserve expansion plans.

2.2.2 SCENARIO 1 – "SMALL GH_2" (by 2030)

The Boegoebaai Port and SEZ are developed and a five (5) GW electrolyser producing 0.5 million tonnes GH_2 per annum (Mtpa) and its derivatives are supported by 10 GW of renewable energy (the scenario assumes 60% solar; 40% wind).

2.2.3 SCENARIO 2 – "BIG GH_2" (by 2050)

The Boegoebaai Port and SEZ are expanded and GH_2 development is upscaled to a 40 GW electrolyser producing a total of 4 Mtpa GH_2 and its derivatives supported by 80 GW of renewable energy (the scenario assumes 60% solar; 40% wind).

2.3 Infrastructure Types impacting Avifauna within the Namakwa Region

2.3.1 Renewable energy and electrical grid infrastructure

While some wind and solar PV generation will be located near the SEZ, the sensitivity of the local environment and potential coastal impacts (e.g., corrosion) mean that most power will come from dispersed renewable projects, often several hundreds of kilometres distant, each requiring its own site-specific environmental impact assessment (EIA) (Error! Reference source not found.). Electricity will be supplied to the GH_2 production plant via new transmission and distribution infrastructure (Table 2).

Table 1: Brief description of the main renewable energy-related infrastructure aspects (Source: CSIR, 2025)

Renewable energy	Aspect	Description
Wind	Turbines	Rotor with blades, nacelle, tower, generating capacity of 4-8 MW per turbine, hub height 150-180 m, blade length ~100 m
	Associated infrastructure	Foundations (~32 m^2), access roads, battery energy storage system (BESS), on-site electrical system, substations, transmission lines, construction camp, operations and maintenance facilities, meteorological masts, communication towers.
Solar PV	Solar panels	Monocrystalline/polycrystalline silicon cells, panel height ~6 m, fixed or dual-axis tracking, single or bifacial modules.
	Associated infrastructure	Inverters, mounting structures, BESS, foundations, access roads, electrical system, substations, transmission lines, electrical components, construction camp, operations and maintenance facilities.

Note that the typical parameters for wind and solar PV infrastructure provided in Table 1 above, such as the individual generating capacity of turbines, hub height, blade length and PV panel height, are based on current industry practice. These parameters are used as the assumption in this SEA and are likely to change due to technological advancements in the period to 2050.

Renewable energy (wind and solar) facilities and associated powerline infrastructure can impact avifauna through collision and electrocution risks, particularly for large, slow-flying or migratory species; habitat loss or alteration from facility footprints; and disturbance from noise, lighting, and human activity. Poorly sited wind or solar installations can displace sensitive species or increase mortality due to collisions in areas of suitable habitat and high-use bird corridors. Powerlines may also create barrier effects, disrupting flight paths and access to key foraging or breeding areas. Careful siting, bird-friendly pylon design, and proper marking of powerlines can reduce these risks.

2.3.2 Green hydrogen plants

Green hydrogen plants are the core production hubs that turn water and renewable electricity into a storable, transportable, and versatile clean fuel. This makes them central to both the green hydrogen value chain and the broader renewable energy transition (Table 2). Green hydrogen plants are the conversion engines that link renewable energy generation to a wide range of low-carbon applications, while also accelerating renewable energy deployment, enabling deep decarbonisation, and creating new economic opportunities.

Green hydrogen plants themselves do not usually pose the same direct collision or displacement risks to birds as wind turbines or tall transmission structures. However, they can still have considerable, often indirect avifaunal impacts because they are rarely stand-alone facilities. They are typically part of a much larger infrastructure footprint that includes renewable energy generation, electricity transmission, water supply and export logistics. The green hydrogen plant is often the anchor for a web of associated infrastructure. While the plant's core process is relatively benign to birds, its enabling components i.e., the renewable energy generation, electricity transmission, water supply and export facilities can create substantial avifaunal risks if not carefully sited, designed and managed.

2.3.3 Desalination plants

Desalination plants are critical enabling links in many large-scale green hydrogen projects, especially in coastal or arid regions where freshwater is scarce, but renewable energy potential is high (**Table 2**). Desalination plants make it possible to turn abundant seawater into the ultra-pure feedstock electrolysers need, unlocking green hydrogen production in water-scarce but renewable-rich regions, while also offering opportunities for community water supply and integrated, low-carbon infrastructure.

Desalination plants can affect avifauna primarily through habitat disturbance during construction and operation, noise and lighting impacts that may disrupt breeding or foraging behaviour, and indirect effects from associated marine infrastructure. Coastal intakes and brine discharge can alter nearshore ecosystems, potentially reducing prey availability for birds favouring the littoral active zone, while increased human activity and vessel traffic may disturb roosting and nesting sites.

2.3.4 Roads, rail and pipelines

Transport infrastructure such as roads, railways and pipelines (**Table 2**) can impact avifauna through habitat loss and fragmentation, disturbance by noise, vibration and lighting, as well as increased collision risk with vehicles, trains or overhead powerlines. Linear corridors may also create barrier effects, altering flight paths and access to feeding or breeding areas, while construction and maintenance activities can disrupt nesting and foraging. In sensitive habitats, these impacts can be significant, especially for large, low-manoeuvrability or ground-nesting bird species.

The following transport infrastructure is planned in the broader Namakwa Region:

- New pipelines for the bulk transport of GH_2 to and from Namibia, Saldanha Bay (Scenario 1) and Prieska (Scenario 2).
- New rail between the Boegoebaai Port and Kenhardt connecting to the existing Saldanha-Sishen railway route.
- Upgrade and expansion of roads to and from Alexander Bay.
- Roads associated with the construction, operation and maintenance of new renewable energy facilities, railways and pipelines.

2.3.5 Masts and towers

Masts and turbines are the vertical backbone of green hydrogen infrastructure, from capturing the wind that powers electrolysers, to gathering the climate data that underpins investment decisions, to enabling communications and control systems that keep complex, distributed renewable-hydrogen networks running smoothly.

Masts and towers can impact avifauna mainly through collision risk, particularly for large, fast-flying or nocturnal species attracted to or disoriented by lights. Guy wires on tall masts increase this risk. They may also cause habitat displacement if placed in sensitive areas and serve as perching or nesting sites for some species, which can lead to increased predation pressure or exposure to operational hazards. Careful siting, design, and proper marking can reduce these risks.

Table 2: GH2 development scenario quantifications (Scenario 1 and Scenario 2) for the Namakwa regional assessment (Source: CSIR, 2025)

	Aspect	Unit	Sc1: Small GH_2	Sc2: Big GH_2	*Assumptions*
SEZ	Electrolyser capacity	GW	5	40	Northern Cape Green Hydrogen Master Plan ambition
	Electrolyser footprint	ha	75	600	15 ha per 1 GW
	GH2 volume	mtpa	0,5	4,0	10 GW electrolyser = 1 mpta GH2
	GH2 storage footprint	ha	250	2 000	10 ha per 20 000 tpa (500 ha for 1 mpta)
	Ammonia volume	mtpa	2,8	22,7	1 mt H2 for 5,67 mt NH3 (1Mt of ammonia contains 176.5 kg (just 17.65%))
	Ammonia footprint	ha	57	454	1 ha per 50 000 tpa NH3 (e.g. Enertrag Hendrina) (20 ha for 1 mtpa)
	Ammonia storage footprint	ha	28	227	0,5 ha per 50 000 tpa NH3 (e.g. Enertrag Hendrina) (10 ha for 1 mpta)
	Desalination output volume	Ml/day	36	286	25 kg water per 1 kg GH2 (considering electrolysis and cooling). 1Mtpa GH2 output required 25 Mtpa (=25000 MLpa) water / 350 operational.
	Desalination footprint	ha	7	57	5 Ml/day output needs 1 ha
	Desalination discharge	Ml/day	48	387	Ratio of desalinated water to brine discharge water to be 42.5:57.5. (i.e 42.5% of intake sea water is converted to desalinated water and 57.5% is discharged as brine).
	Pipeline intake volume	Ml/day	84	672	Output + discharge
REGION	RE capacity total	GW	10	80	1 Mt/yr of H2 needs 10 GW electrolyser, that is powered by 20 GW
	RE capacity - solar	*GW*	*6*	*48*	60 % solar : 40 % wind
	RE footprint - solar	*ha*	*12 000*	*96 000*	0,5MW/ha
	RE extent - solar		*12 000*	*96 000*	Footprint = extent
	RE facilities - solar	*no of facilities*	*6*	*48*	Clusters of 1 GW facilities
	RE capacity - wind	*GW*	*4*	*32*	60 % solar : 40 % wind
	RE footprint - wind	*ha*	*4 000*	*32 000*	1 MW/ha
	RE extent - wind	*ha*	*40 000*	*320 000*	0,1 MW/ha
	RE facilities - wind	*no of facilities*	*3*	*21*	Clusters of 1,5 GW facilities
	Road length	km	300	600	New roads and upgrades same distances / routes as pipelines
	Road footprint	ha	1 200	2 400	40 m (Rural class 2 road 40-70 m. TRH26 Road Classification and Access Management)
	Rail length	km	550	550	Boegoebaai – Kenhardt. New rail direction south-east to connect to the existing Saldanha-Sishen route.
	Rail footprint	ha	1 600	1 650	30 m for rail and service track
	Pipeline length	km	300	600	Sc1: NAM<BB>SB (300km); Sc2: BB>Prieska (300km)
	Pipeline footprint	ha	600	1 200	20 m servitude
	Powerline length	km	260	1 387	Assume grid strengthening / shared infrastructure 30 km TX associated with each RE cluster.
	Powerline footprint	ha	1 300	6 933	50 m servitude (TRH 27 South African Manual for Permitting Services in Road Reserves)
	Main infrastructure components footprint	**ha**	**21 082**	**142 240**	
Units: GW = gigawatt; mtpa = million tonne per annum; ha = hectare; Ml/day = million litres per day; km = kilometre					

3. KEY POTENTIAL IMPACTS ON AVIFAUNA

3.1 Displacement due to Disturbance

The construction phase of any proposed development associated with the Boegoebaai Port and SEZ (see Section 2.2 and 2.3 above) can disturb bird populations and their habitats, particularly if construction activities occur in or near areas that birds rely on for nesting, feeding, or roosting. Birds are highly sensitive to changes in their environment, and the disruption caused by the construction and operation of the proposed project can have several adverse effects.

The noise and activity associated with vehicles, machinery and construction operations can disturb birds, especially those sensitive to human presence or loud sounds. Species that require quietness and undisturbed environments for nesting or breeding may abandon their nests if they perceive the area as unsafe or stressful. This disturbance can disrupt breeding cycles, leading to reduced reproductive success and therefore population decline.

Additionally, the presence of machinery and vehicles can pose direct threats to birds through collisions or accidental disturbances. Birds, particularly ground-nesting species, or those flying low over the area, may be at risk of injury or mortality from these activities.

The construction and operation of the proposed development may involve several activities aimed at excavating, processing, and utilising materials for construction purposes. Some of the activities which could be associated with the proposed development, which could cause species displacement due to disturbance, include:

- Site Selection and Preparation: This involves identifying suitable locations for the proposed development based on proximity to construction sites needing materials and the quality of materials available. Site preparation may include clearing vegetation and levelling the area.

- Excavation: The primary construction activity could be excavation, where soil, gravel, sand, or other materials are extracted from the ground using heavy machinery such as excavators, bulldozers, or loaders. This activity will be a significant source of noise and movement disturbance.

- Material Processing: Excavated materials often need processing to meet specific size and quality requirements for construction. This can involve crushing, screening, or washing the materials to remove impurities to ensure consistency.

- Material Stockpiling: Processed materials are stockpiled onsite for storage and subsequent transportation to construction sites. Proper stockpiling techniques are important to prevent erosion, maintain material quality, and ensure safety.

- Transportation: Transporting materials for the proposed project to construction sites is a significant part of operations. This may involve using trucks, conveyor belts, or other equipment to move materials efficiently and safely.

3.2 Displacement due to Habitat Loss / Fragmentation / Transformation

Construction activities and infrastructure, such as pipelines, powerlines and roads, can fragment habitats and restrict species movement / dispersal. Renewable energy developments in addition to the port related and green hydrogen developments can have significant impacts on avifauna, primarily through habitat loss and degradation. The construction and expansion of ports often involve land reclamation, dredging, and the destruction of wetlands and intertidal zones, which are critical habitats for many bird species (Dugan, 1990; BirdLife International, 2021). These areas serve as feeding, nesting, and roosting sites, particularly for migratory shorebirds that rely on undisturbed coastal habitats during their journeys (Goss-Custard & Verboven, 1993). In addition, the construction of renewable energy (wind and solar) facilities, their associated electricity grid infrastructure and their extensive road network require the clearance of large areas of vegetation, earthworks and often trenching for foundations and component installations.

The loss of vegetation and natural landscapes disrupts ecological balance, leading to reduced food availability and increased competition among avian species (Ma et al. 2014). Pollution from port operations, including possible oil spills and chemical runoff, can degrade water quality and affect the health of aquatic ecosystems, further impacting bird populations dependent on these areas (Boersma et al. 2001). Such habitat loss and fragmentation can result in declining bird populations, threatening the biodiversity of avian communities in and around the proposed Port Expansion Area, as well as within the Namakwa Region.

3.3 Injury or Mortality due to Collisions

Wind energy generation has experienced rapid worldwide development over recent decades as its environmental impacts are considered to be relatively lower than those caused by traditional energy sources, with reduced environmental pollution and water consumption (Saidur et al. 2011). However, bird fatalities due to collisions with wind turbines and associated infrastructure such as powerlines, substations, communications towers and/or meteorological masts have been consistently identified as a main ecological drawback to wind energy (Drewitt & Langston, 2006).

Collisions with wind turbines appear to kill fewer birds than collisions with other man-made infrastructures, such as powerlines, buildings or even traffic (Erickson et al. 2005). Nevertheless, estimates of bird deaths from collisions with wind turbines worldwide range from 0 to almost 40 deaths per turbine per year (Sovacool, 2009). The number of birds killed varies greatly between sites, with some sites posing a higher collision risk than others, and with some species being more vulnerable than others. These numbers may not reflect the true magnitude of the problem, as some studies do not account for detectability biases such as those caused by scavenging, searching efficiency and search radius (Bernardino et al. 2013; Erickson et al. 2005; Huso & Dalthorp, 2014). Additionally, even for low fatality rates, collisions with wind turbines may have a disproportionate effect on some species. For long-lived species with low productivity and slow maturation rates (e.g. raptors), even low mortality rates can have a significant impact at the population level (Carrete et al. 2009; Drewitt & Langston, 2006).

High bird fatality rates at several wind farms have raised concerns among the industry and scientific community in South Africa and abroad. According to the latest BirdLife South Africa (BLSA) report on bird fatalities at operational wind farms, a total of 2444 unique bird fatality incidents were recorded at wind farms, with losses attributed to turbine collisions, powerlines and other anthropogenic impacts. These incidents involved 202 bird species. Of these, 198 were recorded as turbine collisions (BLSA, 2025). The situation is even more critical for Species of Conservation Concern (SCC) which sometimes are most at risk.

High profile examples include the Altamont Pass Wind Resource Area (APWRA) in California because of high fatality of Golden eagles (*Aquila chrysaetos*), Tarifa in Southern Spain for Griffon vultures (*Gyps fulvus*), Smøla in Norway for White-tailed eagles (*Haliaeetus albicilla*), and the port of Zeebrugge in Belgium for gulls (*Larus* sp.) and terns (*Sterna* sp.) (Barrios & Rodríguez, 2004; Drewitt & Langston, 2006; Everaert & Stienen, 2008; Thelander et al. 2003). Due to their specific features and location, and characteristics of their bird communities, these wind farms have been responsible for a large number of fatalities that culminated in the deployment of additional measures to minimize or compensate for bird collisions. However, currently, no simple formula can be applied to all sites; in fact, mitigation measures must inevitably be defined according to the characteristics of each wind farm and the diversity of species occurring there (Marques et al. 2014). An understanding of the factors that explain bird collision risk and how they interact with one another is therefore crucial to proposing and implementing valid mitigation measures (BLSA, 2025).

3.4 Injury or Mortality due to Electrocution

Electrocution refers to the scenario where a bird is perched, or attempts to perch, on the electrical structure and causes an electrical short circuit by physically bridging the air gap between live components and/or live and earthed components (Van Rooyen, 2004). The electrocution risk is largely determined by the voltage of the proposed overhead powerline (OHL) and the pole/tower (pylon) design. Should the proposed OHL be constructed using a 132 kV tower specification, the electrocution impact for the majority of priority species will be negligible. The Cape Vulture is one of the priority species, due to its size and gregarious nature, capable of bridging the clearance distances of an OHL constructed using this specification.

Ordinarily, the construction of a single circuit powerline using the approved bird-friendly pylon/tower design D-DT-7649 in accordance with the Distribution Technical Bulletin titled *Refurbishment of 66/88 kV line kite type frames with D-DT-7649 type top configuration - Reference Number 240-170000467* will eliminate the electrocution risk. The configuration of the insulators and the clearance distances between the live and earthed components on this structure can comfortably accommodate a perching vulture. However, if the OHL is built on lattice structures, it is imperative that there is a minimum clearance of 1.8 m between the jumper cables and/or insulators and the horizontal earthed component on the lattice structure (pers. comm. Lourens Leeuwner - Eskom-EWT Strategic Partnership Manager). Additional mitigation in the form of insulating sleeves on jumper cables present on strain poles and terminal poles must be implemented (if suitable insulation material is readily available); alternatively, all jumper cables must be suspended below the crossarms.

Electrocutions within proposed on-site substations at both the Port Precinct, the SEZ and the renewable energy facilities are possible, however, the likelihood of this impact on the more sensitive SCC is remote, as these species are unlikely to regularly utilise the infrastructure within the on-site substation for perching or roosting. Species that are more vulnerable to this impact are medium-sized raptors, corvids, owls, and certain species of waterbirds.

4. APPROACH AND METHODOLOGY

To assess the avifaunal sensitivity of the Namakwa Region, various datasets were used to compile sensitivity layers for each priority species including SCC. The layers were ranked according to endemicity and conservation status, and fine scale habitat suitability to develop a four-tier sensitivity map. See Section 6.4 for more detail.

A weighted sensitivity modelling approach was applied to generate these layers. For each priority species, spatial predictions from species distribution and habitat suitability models were combined with conservation-weighting factors that accounted for (i) threat status, (ii) range size, and (iii) degree of endemism. These parameters were used to express each species' relative vulnerability to key impact pathways, namely disturbance/displacement, habitat loss, collision, and electrocution. The weighted species layers were then normalised and aggregated to produce cumulative, continuous sensitivity surfaces per impact type. This approach provides a precautionary yet comparable spatial framework across species and impact types, allowing for differentiation of relative ecological risk at a regional scale.

The following information sources and methods were used to conduct this study:

- Bird distribution data from the Second Southern African Bird Atlas Project (SABAP2) was obtained (https://sabap2.birdmap.africa/), to ascertain which species occur in the pentads relevant to the Namakwa Region. A pentad grid cell covers 5 minutes of latitude by 5 minutes of longitude (5' × 5'). Each pentad is approximately 8 × 9 km. To get a more representative impression of the birdlife in the area, a consolidated dataset was obtained for a total of 874 pentads some of which intersect the proposed Port Precinct and SEZ development sites, with the Namakwa Region also referred to as the "study area" (**Figure**). This SABAP2 dataset is therefore based on avifaunal species presence recorded within the study area since 2007 (i.e., 18 years).

- The SABAP2 data in this region is usually not as comprehensive as in the rest of South Africa due to decreased observer effort (fewer people living in the area and access difficulty), therefore the data was supplemented by species distribution models and habitat suitability models as well as general knowledge of the area.

- A target species list was generated by assessing SABAP2 data, BirdLasser citizen science data and intersecting species distribution models for the Namakwa Region that includes the originally assessed 5 km Proposed Area of Impact (PAOI) buffer around the Boegoebaai Port Precinct and SEZ (AfriAvian WP1 Avifaunal Assessment, April 2025). This assessment of all available data yielded a priority list of 44 threatened and/or endemic avian species that were included in the analysis. Species distribution models have been developed for more than >100 SCCs as part of a national assessment of avian sensitivity. Species distribution models were developed using a standardised methodology that is aligned with what was used to develop avian models for the DFFE National Screening Tool.

- For the habitat suitability models, a classification of the vegetation types of the Namakwa region was obtained from the First Atlas of Southern African Birds (SABAP1) and the 2018 National Vegetation Map compiled by the South African National Biodiversity Institute (Mucina & Rutherford, 2006, as revised by SANBI, 2018).

- The national threatened status of all priority species was determined with the use of the most recent edition of the Red List Book of Birds of South Africa, Lesotho, and Swaziland (Lee et al. 2025), and the latest authoritative summary of southern African bird biology (Hockey et al. 2005).

- The global threatened status of all priority species was determined by consulting the latest (2024) IUCN Red List of Threatened Species (http://www.iucnredlist.org/).

- The database on the Key Biodiversity Areas (KBAs) of South Africa (Key Biodiversity Areas in South Africa - SANBI) was consulted for information on potentially relevant KBAs within the study area.

- An intensive internet search was conducted to source information on the impacts of the proposed development on avifauna.

- Satellite imagery (Google Earth © 2025) was used to view the study area on a landscape level and to help identify bird habitat on the ground.

- The South African National Biodiversity BGIS map viewer was used to determine the locality of the study area relative to National Protected Areas.

- The DFFE National Screening Tool (https://screening.environment.gov.za/screeningtool/) was used to determine the assigned sensitivity of the study area as it relates to the Animal Species and Avian (Wind) Environmental Themes.

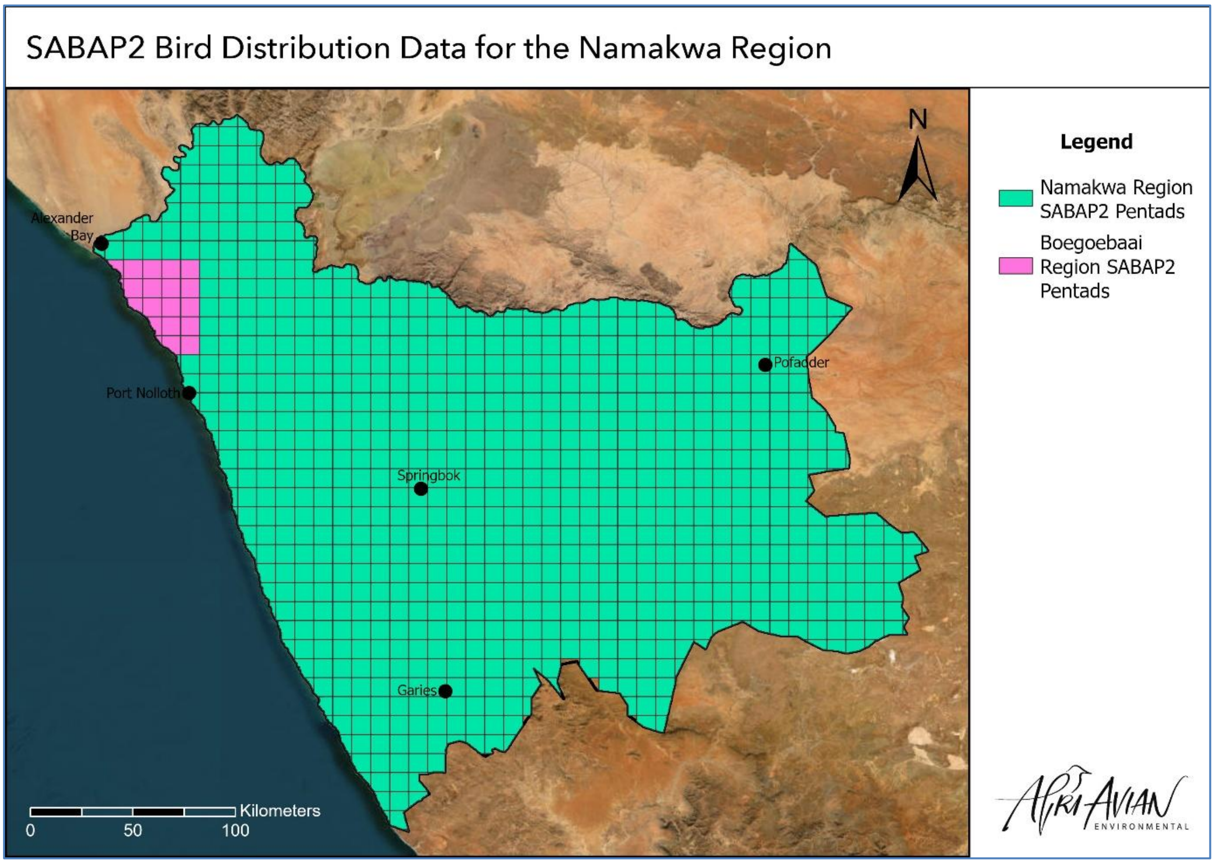

Figure 1: Bird distribution data for the WP2 study area i.e., Namakwa region (indicated in green) has been obtained from 874 SABAP2 pentads. The 20 pentads comprising the WP1 study area i.e., Boegoebaai Port and SEZ are indicated in pink.

5. ASSUMPTIONS AND LIMITATIONS

This study assumed that the sources of information used in this report are reliable. In this respect, the following must be noted:

- The focus of the study is primarily on the potential impacts of the planned development scenarios on priority avifaunal species which were defined as follows:
  - South African Red List species (Species of Conservation Concern)
  - South African endemics and near endemics
  - Waterbirds
  - Raptors; and
  - Species vulnerable to disturbance and/or habitat loss.
- The assessment of impacts is based on the baseline environment as it currently exists within the Namakwa Region and nearby surrounding environment.
- Conclusions in this study are based on experience of these and similar species in different parts of South Africa. Bird behaviour can never be entirely reduced to formulas that will be valid under all circumstances.

- The study area refers to the Namakwa Region that is 5 819 784.13 hectares in extent and covered by the 874 SABAP2 pentads, and that includes the proposed Boegoebaai Port and SEZ development area (**Figure**).

6. KEY ENVIRONMENTAL ATTRIBUTES AND SENSITIVITIES OF THE STUDY AREA

6.1 Habitat Features

The Namakwa Region of the Northern Cape falls largely within the Succulent Karoo Biome, one of the world's biodiversity hotspots, and encompasses a rich mosaic of vegetation types that are classified based on climate, geology, soils, and plant communities (Mucina & Rutherford, 2006).

These vegetation types within the Succulent Karoo and the adjacent Desert, Fynbos and Nama Karoo biomes, range from arid winter-rainfall shrublands of the Lowland Succulent Karoo to the endemic-rich rocky slopes of the Upland Succulent Karoo/Kamiesberg Mountain Scrubland. Coastal habitats include Namaqualand Strandveld on calcareous sands, Coastal Duneveld with stabilised and mobile dunes, and Seashore Vegetation on rocky and sandy shores. Seasonal floral displays occur in the Namaqualand Blomveld, while inland sandy plains are represented by Inland Duneveld and Oograbies Plains Sandy Grassland. Unique features include Heuweltjiesveld on nutrient-rich termite mounds, Klipkoppe Scrubland with localised succulent endemics, and Riethuis–Wallekraal Quartz Vygieveld with specialised quartz-patch flora. Additional habitats comprise Namaqualand Sand Fynbos on sandstone soils, Arid Grassland in the eastern interior, ephemeral Namaqualand Rivers with riparian woodland, and saline wetlands such as Salt Pans and Arid Estuarine Salt Marshes, which are vital for waterbirds (Mucina & Rutherford, 2006; as revised by SANBI, 2018).

The Namakwa Region further includes several formally Protected Areas, declared in terms of the National Environmental Management: Protected Areas Act (Act No. 57 of 2003, as amended by Act 2 of 2022, such as the |Ai-|Ais/Richtersveld Transfrontier Park, the Namakwa National Park, Gamsberg Nature Reserve and the Goegap Nature Reserve (DFFE, 2022).

The Namakwa Region also comprises 15 Key Biodiversity Areas (KBAs). KBAs are 'sites that contribute significantly to the global persistence of biodiversity', which means they are the most important places in the world for species and their habitats – whether these be in terrestrial, freshwater, estuarine, or marine ecosystems. Sites qualify as global KBAs if they meet the specific standardised criteria and quantitative thresholds focused on one or more of five trigger aspects; threatened biodiversity, geographically restricted biodiversity, ecological integrity, biological processes, and irreplaceability through quantitative analysis.

KBAs featured within the Namakwa Region (**Figure**) include the following:

a) Aggeneys - Pella - Pofadder
b) Bushmanland Inselbergs
c) Bushmanland Interior
d) Gariep Desert
e) Goegap
f) Kamiesberg
g) Kliprand
h) Namaqualand Sandveld North
i) Namaqua National Park
j) Namaqualand Hardeveld North
k) Namaqualand Hardeveld South

l) Namaqualand Sandveld South
m) Orange River Estuary - Southern Namib Desert
n) Richtersveld National Park
o) Southern Richtersveld

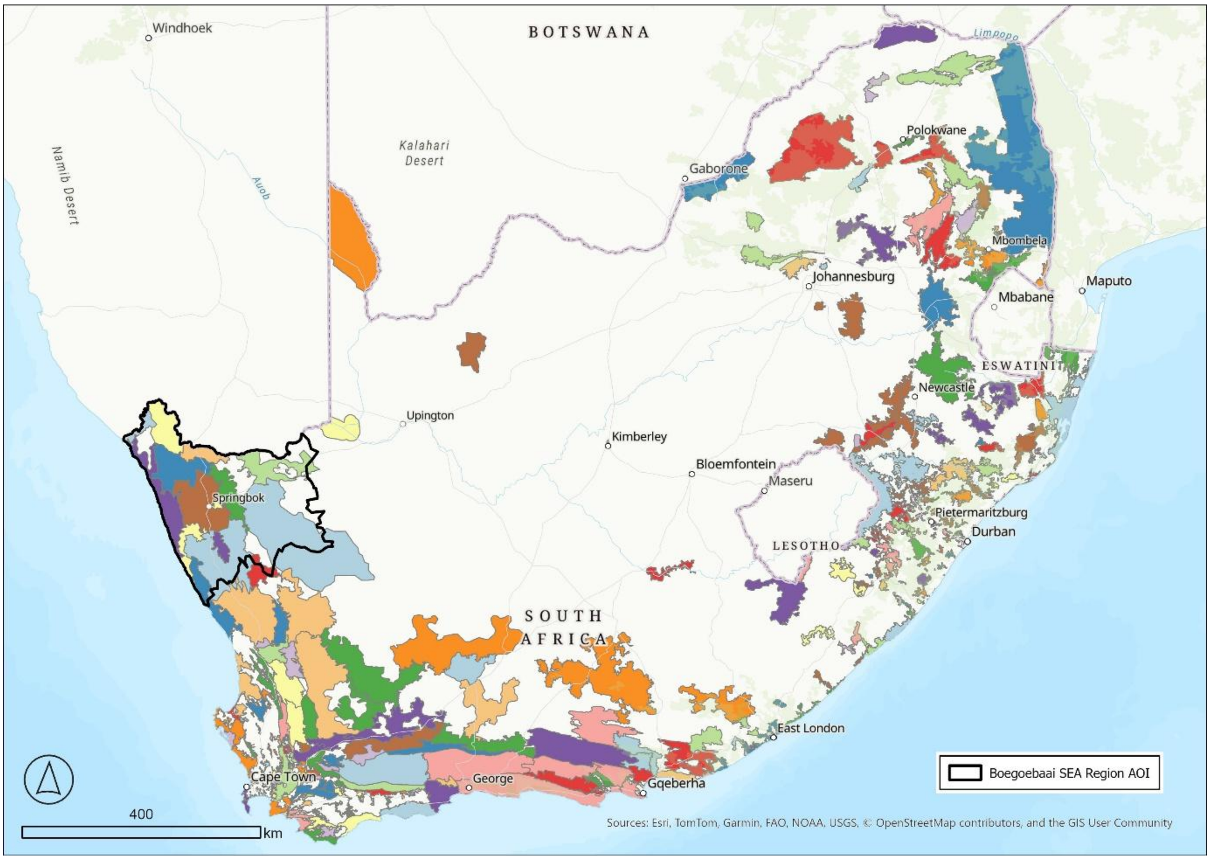

Figure 1: The Namakwa Region of South Africa (outlined in black) contains 15 Key Biodiversity Areas (Source: https://www.keybiodiversityareas.org/map).

6.2 Priority Bird Species of the Namakwa Region

To date, one hundred and thirty-eight (138) bird species have been recorded in the Namakwa Region through the Second Southern African Bird Atlas Project (SABAP2) over a period of 18 years. Of the 138 species, 44 are considered priority species. Priority species were defined as species that are particularly sensitive to displacement due to disturbance and/or habitat loss, as well as risk of collisions and electrocutions; endemic and near-endemic species; all SCC; waterbirds; raptors; and range restricted species. The 44 priority bird species recorded in the Namakwa Region that were selected for further assessment include SCC as well as those that are endemic or near-endemic to South Africa (**Table**).

It should be noted that observer effort in this area is generally low due to the sparseness of the human population and the remoteness (inaccessibility) of the area. Therefore, the SABAP2 species list is not necessarily fully comprehensive of the Namakwa Region.

Table 3: Priority avifaunal species including Species of Conservation Concern and/or endemic species that have been recorded in the Namakwa Region as it relates to the SEA. CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened, E = Endemic, NE = Near Endemic, SLE = Endemic to South Africa, Lesotho and Eswatini

Species Name	Scientific Name	Global Conservation Status	Regional Conservation Status	Endemism
African Fish Eagle	*Icthyophaga vocifer*	-	-	-
African Marsh Harrier	*Circus ranivorus*	-	VU	-
African Rock Pipit	*Anthus crenatus*	NT	-	SLE
Bank Cormorant[3]	*Phalacrocorax neglectus*	EN	EN	-
Bateleur	*Terathopius ecaudatus*	EN	EN	-
Black Harrier	*Circus maurus*	EN	EN	NE
Black Stork	*Ciconia nigra*	-	EN	-
Black-eared Sparrow-Lark	*Eremopterix australis*	-	-	NE
Black-headed Canary	*Serinus alario*	-	-	NE
Blue Crane	*Grus paradisea*	VU	VU	-
Burchell's Courser	*Cursorius rufus*	-	VU	-
Cape Cormorant[4]	*Phalacrocorax capensis*	EN	EN	-
Cape Clapper Lark	*Mirafra apiata*	-	-	NE
Cape Eagle-Owl	*Bubo capensis*	-	-	-
Cape Long-billed Lark	*Certhilauda curvirostris*	-	-	E
Cape Rock Thrush	*Monticola rupestris*	-	-	SLE
Cape Spurfowl	*Pternistis capensis*	-	-	NE
Cape Sugarbird	*Promerops cafer*	-	-	E
Cape Vulture	*Gyps coprotheres*	VU	VU	-
Caspian Tern	*Hydroprogne caspia*	-	VU	-
Chestnut-banded Plover	*Anarhynchus pallidus*	-	VU	-
Cinnamon-breasted Warbler	*Euryptila subcinnamomea*	-	-	NE
Curlew Sandpiper	*Calidris ferruginea*	VU	VU	-
Damara Tern	*Sterna balaenarum*	-	EN	-
Dune Lark (Coastal)	*Calendulauda erythrochlamys patae*	-	-	NE
Great White Pelican	*Pelecanus onocrotalus*	-	VU	-
Greater Flamingo	*Phoenicopterus roseus*	-	NT	-
Grey-winged Francolin	*Scleroptila afra*	-	-	SLE
Ground Woodpecker	*Geocolaptes olivaceus*	NT	NT	SLE
Jackal Buzzard	*Buteo rufofuscus*	-	-	NE

[3] Marine species were not included in this Terrestrial Avifaunal Study. Marine species assessments are included in the Marine Specialist Study for the Boegoebaai SEA.
[4] Marine species were not included in this Terrestrial Avifaunal Study. Marine species assessments are included in the Marine Specialist Study for the Boegoebaai SEA.

Species Name	Scientific Name	Global Conservation Status	Regional Conservation Status	Endemism
Karoo Eremomela	*Eremomela gregalis*	-	-	NE
Karoo Korhaan	*Heterotetrax vigorsii*	-	NT	-
Lanner Falcon	*Falco biarmicus*	-	NT	-
Ludwig's Bustard	*Neotis ludwigii*	EN	EN	-
Maccoa Duck	*Oxyura maccoa*	EN	VU	-
Martial Eagle	*Polemaetus bellicosus*	EN	EN	-
Orange-breasted Sunbird	*Anthobaphes violacea*	-	-	E
Peregrine Falcon	*Falco peregrinus*	-	-	-
Red Lark	*Calendulauda burra*	VU	VU	E
Sclater's Lark	*Spizocorys sclateri*	NT	NT	NE
Secretarybird	*Sagittarius serpentarius*	EN	VU	-
Sentinel Rock Thrush	*Monticola explorator*	NT	-	SLE
Southern Black Korhaan	*Afrotis afra*	VU	VU	E
Verreaux's Eagle	*Aquila verreauxii*	-	VU	-

6.3 DFFE Screening Tool

The Namakwa Region is classified partially as High, Medium and Low sensitivity for avifauna according to the Animal Species Theme of the DFFE Screening Tool (**Figure 2**). The Namakwa Region is classified partially as Very High, High, Medium and Low sensitivity for avifauna according to the Avian (Wind) Theme of the DFFE Screening Tool (**Figure 3**). The Namakwa Region also contains confirmed habitat for SCC as defined in the Protocol for the specialist assessment and minimum report content requirements for environmental impacts on terrestrial animal species (Government Gazette No 43855, Government Notice 1150 of 30 October 2020). SCCs are listed on the IUCN Red List of Threatened Species (2025) or South Africa’s National Red List (2025) as Critically Endangered, Endangered, Vulnerable or Near Threatened.

The occurrence of SCC in the Namakwa Region is confirmed by the SABAP2 data as indicated in **Table 3** (Section 6.2).

Based on the confirmed habitat, the SABAP2 data, and modelling outputs the overall classification of **Very High** and **High** sensitivity for avifauna in the Screening Tool is supported.

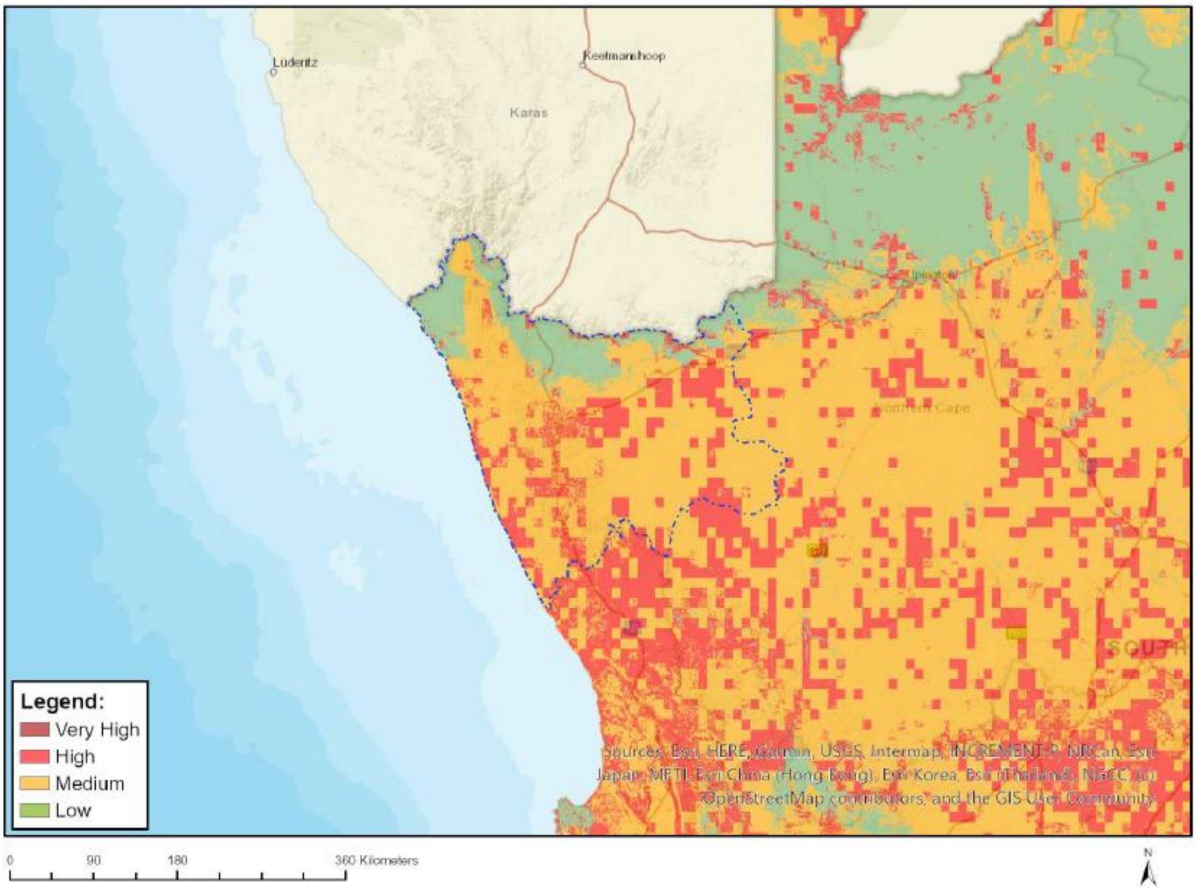

Figure 2: The sensitivity of the Namakwa Region as it relates to the Animal Species Theme (Source: DFFE Screening Tool, 2025).

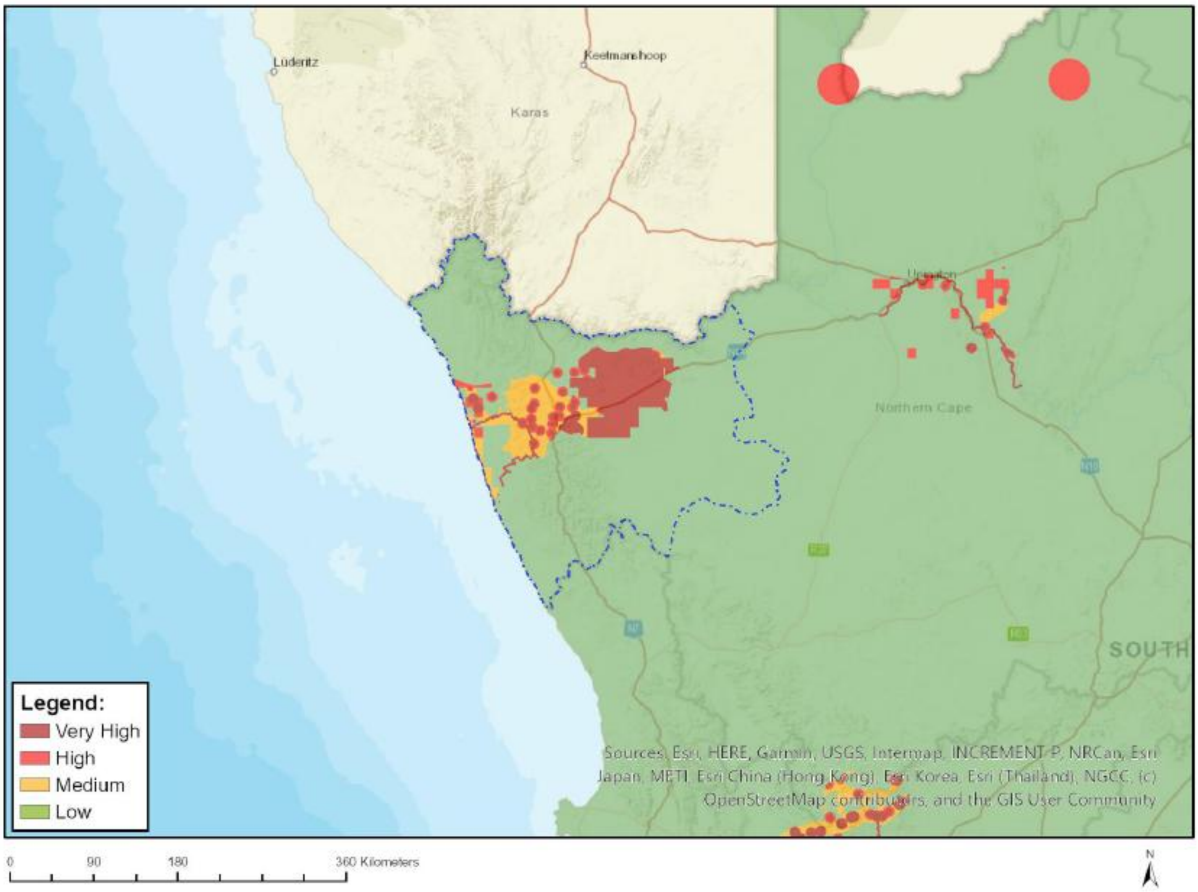

Figure 3: The sensitivity of the Namakwa Region as it relates to the Avian (Wind) Theme (Source: DFFE Screening Tool, 2025).

6.4 Sensitivity Analysis and Mapping

6.4.1 Study Area Definition

The sensitivity analysis for this risk assessment was conducted within the study area defined as the Namakwa Region, encompassing the Richtersveld, Nama Khoi, Kamiesberg, and Khâi-Ma Local Municipalities (including the Boegoebaai Port Precinct and SEZ) in the Northern Cape Province. The analysis area was defined using the established Area of Interest (AOI) polygon to ensure consistent spatial boundaries and exclude background areas that could bias statistical analyses.

6.4.2 Species Data and Distribution Modelling

- *Species Distribution Model Processing*

Species occurrence data and corresponding habitat suitability models were obtained from existing Species Distribution Model (SDM) datasets for the Namakwa Region. The SDM processing workflow involved several filtering stages to identify SCCs:

1. **Initial Dataset**: All available SDMs for the study area were compiled, representing the complete range of species with modelled habitat distributions.

2. **Habitat Threshold Filtering**: Species were filtered based on a minimum habitat area threshold of 5000 hectares within the study area (i.e. the species was distributed across ≥0.1% of the study

area). This threshold was applied to focus the analysis on species with sufficient habitat representation to warrant detailed impact assessment.

3. **Final Species Set**: Species meeting the habitat threshold criteria were retained for detailed impact scoring, while those below the threshold were excluded from quantitative risk assessment but documented for completeness. See **Annexure A** for details.

➢ *Species Attribute Integration*

Species-specific conservation attributes were integrated from authoritative databases for the 44 priority avian species that were selected for this risk assessment, including:

- South African Red Data Book (Lee et. al. 2025) conservation status classifications (CR, EN, VU and NT)
- Range size categories (Small, Medium, Large)
- Endemism classifications (Endemic, Sub-regional endemic, Near endemic)

6.4.3 Impact Scoring Framework

➢ *Impact Type Classification*

Four primary impact categories were assessed based on GH_2 and renewable energy related infrastructure effects on terrestrial avifauna:

1. **Displacement - Disturbance**: Behavioural avoidance and habitat abandonment due to human activities and infrastructure presence.
2. **Displacement - Habitat Loss/ Fragmentation/ Transformation**: Direct habitat loss through infrastructure footprint and associated developments.
3. **Collisions**: Direct mortality from collisions with infrastructure such as wind turbines, powerlines and masts/towers.
4. **Electrocutions**: Mortality from electrocution on transmission and distribution infrastructure.

➢ *Base Impact Scoring per Impact Category*

Species-specific susceptibility scores (0-5 scale) were assigned for each impact type based on:

- Literature review of species-specific vulnerability assessments;
- Expert knowledge of species ecology and behaviour; and
- Documented impacts from comparable developments typical of the GH_2 and renewable energy sectors.

6.4.4 Conservation Weighting System

A multiplicative weighting system was applied to base impact scores to prioritise species of higher conservation concern. See **Annexure A** for details:

➢ *Red Data Status Multipliers*

  - Critically Endangered (CR): 16×
  - Endangered (EN): 8×

- Vulnerable (VU): 4×
- Near Threatened (NT): 2×
- Least Concern (LC): 1×

➢ *Range Size Multipliers*

- Small range: 10×
- Medium range: 5×
- Large range: 1×

➢ *Endemism Multipliers*

- Endemic (E): 5×
- Sub-regional/local endemic (SLE): 5×
- Near-endemic (NE): 3×
- Not endemic (NA): 1×

6.4.5 Composite Weighting

The final conservation multiplier was calculated as:

Conservation Multiplier = Red Data Multiplier × Range Multiplier × Endemism Multiplier

Final Weighted Score per Impact = Base Impact Score × Conservation Multiplier (**Figure 7-10**)

6.5 Spatial Risk Mapping

6.5.1 Raster Processing

Individual species SDMs were processed to create weighted impact surfaces:

1. *NoData Handling*: NoData values in source rasters were converted to zero to enable mathematical operations while preserving spatial extent.
2. *Weight Application*: Each species' SDM was multiplied by its corresponding weighted impact score for each impact type.
3. *Cumulative Impact Calculation*: Species-specific weighted rasters were summed within each impact category to create cumulative impact surfaces.

6.5.2 Risk Classification

Cumulative impact rasters were classified into four risk categories using custom quantile breaks:

- **Low** Risk: 0-30th percentile (%)
- **Medium** Risk: >30th-60th percentile (%)
- **High** Risk: >60th-80th percentile (%)

- **Very High** Risk: >80th-100th percentile (%)

Quantile breaks were calculated from pixels with values >0 within the AOI (i.e., Namakwa Region) to ensure classification reflected actual impact gradients rather than background areas.

6.6 Quality Assurance

6.6.1 Data Validation

- SDM file integrity was verified through spatial extent and value range checks.
- Species name matching between SDM datasets and scoring databases was validated using automated and manual fuzzy matching procedures.
- Statistical outliers in scoring and weighting calculations were identified and verified.

6.6.2 Process Validation

- Incremental processing approaches were implemented to enable resumable workflows and individual species verification.
- Classification results were cross validated against alternative statistical methods (natural breaks, equal intervals) to ensure robustness.
- Final risk maps were visually inspected for spatial coherence and ecological plausibility.

6.7 Synthesis of Avian Sensitivity Mapping for Renewable Energy Technologies

The weighted species-impact modelling for 44 priority avifaunal species produced four primary sensitivity layers corresponding to key renewable energy impact pathways: disturbance/displacement, habitat transformation, collision, and electrocution (**Figures 7–10**). Together, these depict the relative ecological sensitivity of the Namakwa Region to large-scale renewable energy development (**Figure 11**).

While these maps share a common baseline of species-level ecological vulnerability, their dominant drivers differ between wind and solar PV infrastructure. Accordingly, two broad synthesis layers can be interpreted:

6.7.1 Sensitivity to Wind Energy Development

Wind energy infrastructure poses elevated risks of collision (with turbine blades, towers, and associated powerlines) and electrocution (on transmission infrastructure), as well as localised disturbance during construction and operation. The combined collision plus electrocution sensitivity surface therefore provides the most representative indicator of wind-related avian sensitivity.

At the regional scale, areas of Very High sensitivity correspond largely to:

- the Kamiesberg uplands and escarpment zones,
- the Springbok–Garies corridor, and
- parts of the coastal plain south of Port Nolloth, where raptor and large terrestrial species densities are elevated and flight activity intersects likely turbine-suitable topography.
- These zones align closely with previously mapped Key Biodiversity Areas (KBAs) and regions already classified as Very High sensitivity under the DFFE National Screening Tool.

6.7.2 Sensitivity to Solar PV Development

Solar PV installations have comparatively lower direct collision or electrocution risk but can result in habitat loss, fragmentation, and displacement of ground-nesting and/or habitat specialist bird species over large footprints. The combined habitat-loss and disturbance sensitivity surface therefore best represents solar-related avian sensitivity.

High and Very High sensitivity areas for solar PV broadly coincide with:

- the central Namaqualand shrublands and mountain foothills east of Springbok,
- the Garies–Kamiesberg–Springbok belt, and
- the southern and inland coastal plains where species richness and breeding habitat overlap with flat, developable terrain.
- Here, the potential for displacement of endemic and/or threatened larks, bustards, and ground-nesting species is greatest.

6.7.3 Interpretation and Application

These technology-specific syntheses highlight complementary but distinct spatial patterns of risk. They are intended to guide strategic-level screening and spatial planning, rather than prescribe exclusion zones. Local sensitivity can vary substantially depending on site characteristics such as habitat type, micro-topography, and proximity to breeding or foraging areas. Therefore, final technology-specific risk assessment and weighting should be refined through site-level EIA processes, informed by detailed avifaunal surveys.

At the SEA scale, these combined sensitivity layers offer an integrated, precautionary basis for identifying areas where:

- wind and solar development should be prioritised toward lower sensitivity zones, and
- pre-construction monitoring and mitigation planning should be emphasised in high-sensitivity zones.

This methodology provides a systematic, transparent, and scientifically defensible approach to quantifying cumulative species impact risks from renewable energy development and related infrastructure expansion across the Namakwa Region.

Following from the spatial risk mapping, the avian sensitivity of the Namakwa Region, generated from the weighted analysis incorporating the 44 priority avian species selected for further assessment per impact, is illustrated below in **Figure 7 – 10**. **Figure 11** depicts the composite avifaunal sensitivity of the Namakwa Region considering all four impact layers at maximum rule.

Figure 6 illustrates the avian sensitivity of the Namakwa Region generated from the weighted analysis incorporating mainly nest/roost location data and GPS tracking data of 10 key priority SCC i.e., Black Harrier, Blue Crane, Cape Vulture, Ludwig's Bustard, Martial Eagle, Red Lark, Sclater's Lark, Secretarybird, Verreaux's Eagle and White-backed Vulture.

The species-impact scoring sheet detailing the information that generated the weighted analysis and subsequent sensitivity ratings for this avifaunal risk assessment, as outlined and discussed above, is included in **Annexure A**.

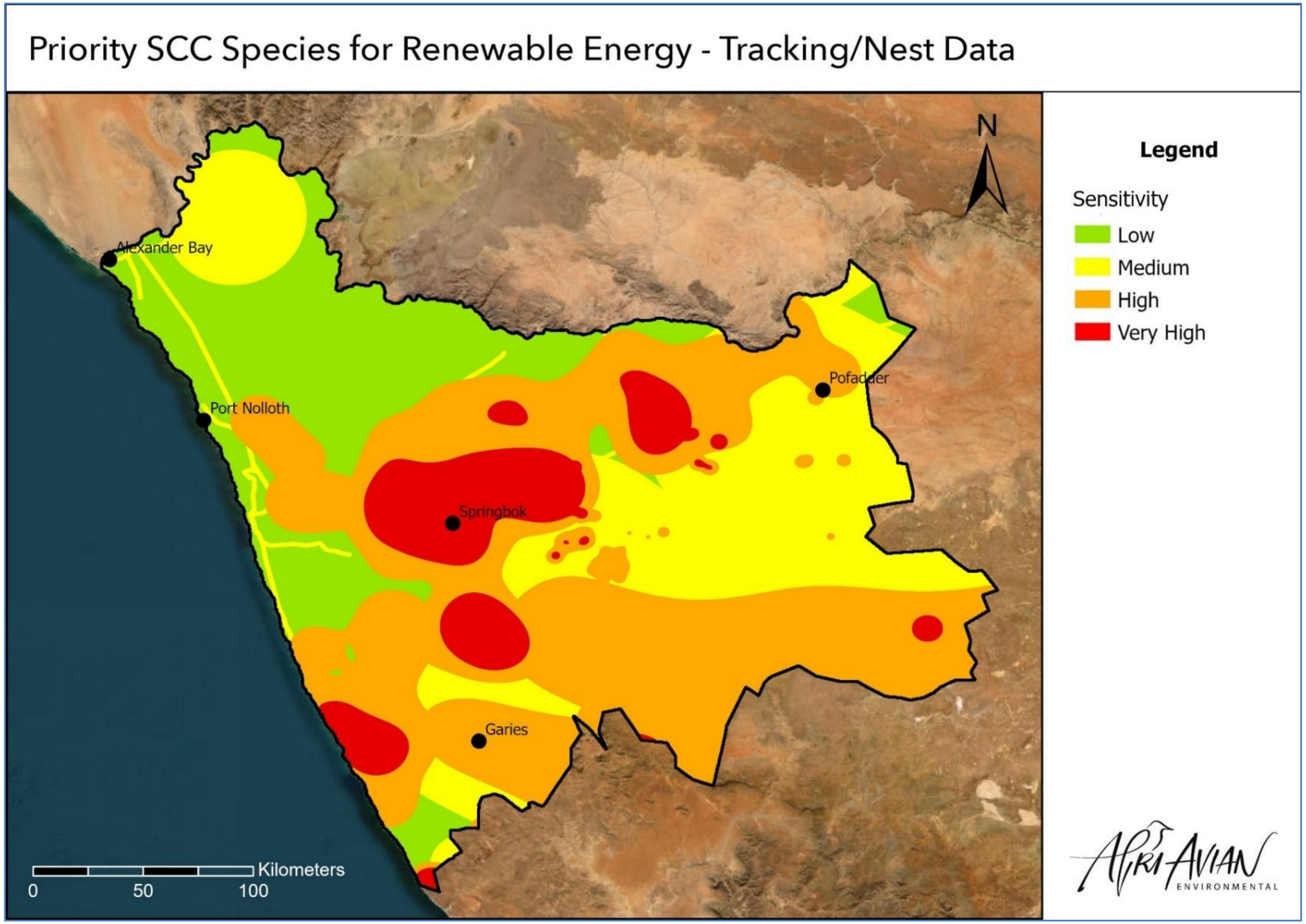

Figure 4: The avian sensitivity of the Namakwa Region generated from the weighted analysis incorporating mainly nest/roost location data and GPS tracking data of 10 key priority SCC.

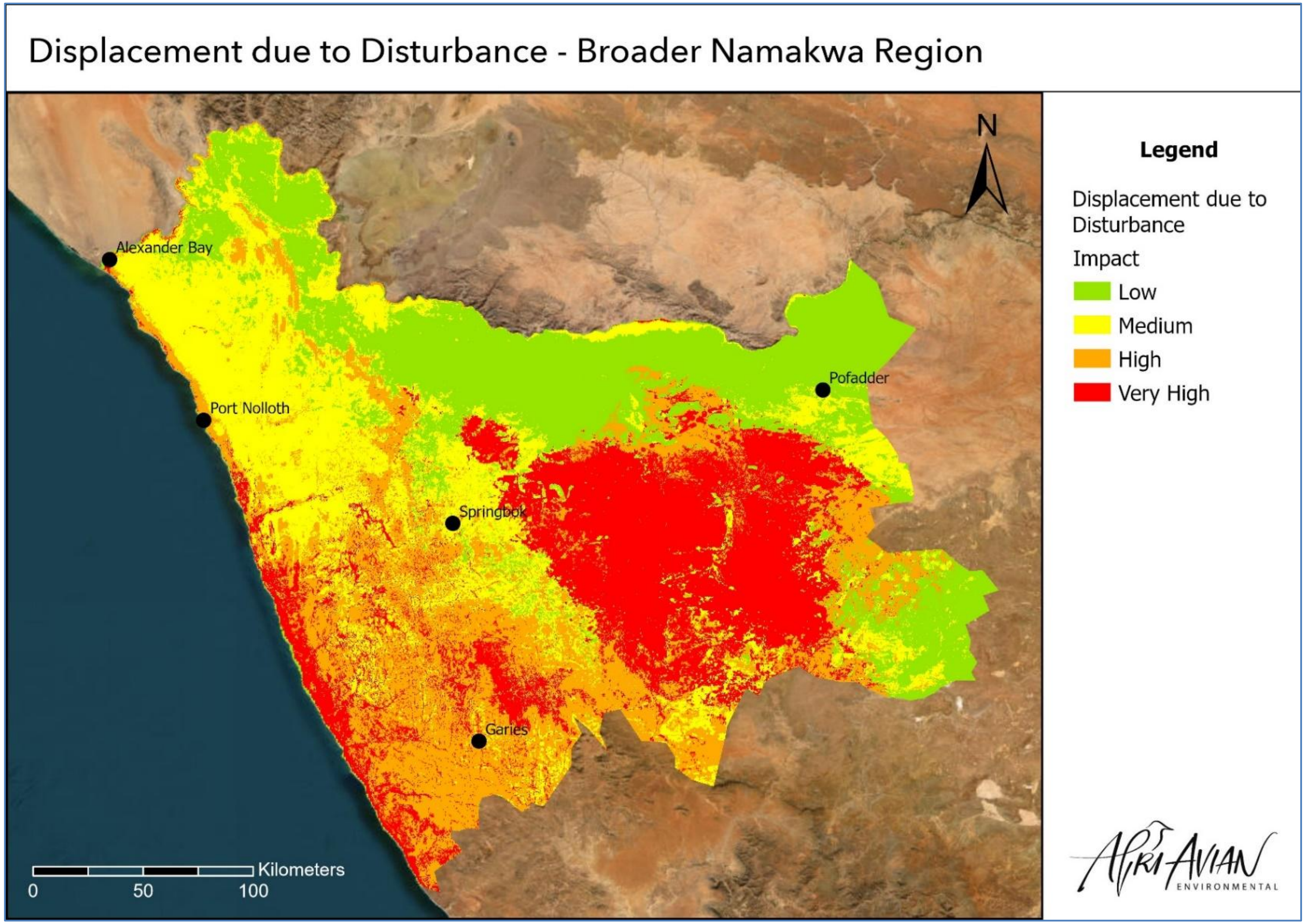

Figure 5: The avian sensitivity of the Namakwa Region generated from the weighted analysis incorporating the 44 priority avian species selected for this risk assessment as it relates to the potential impact of displacement due to disturbance.

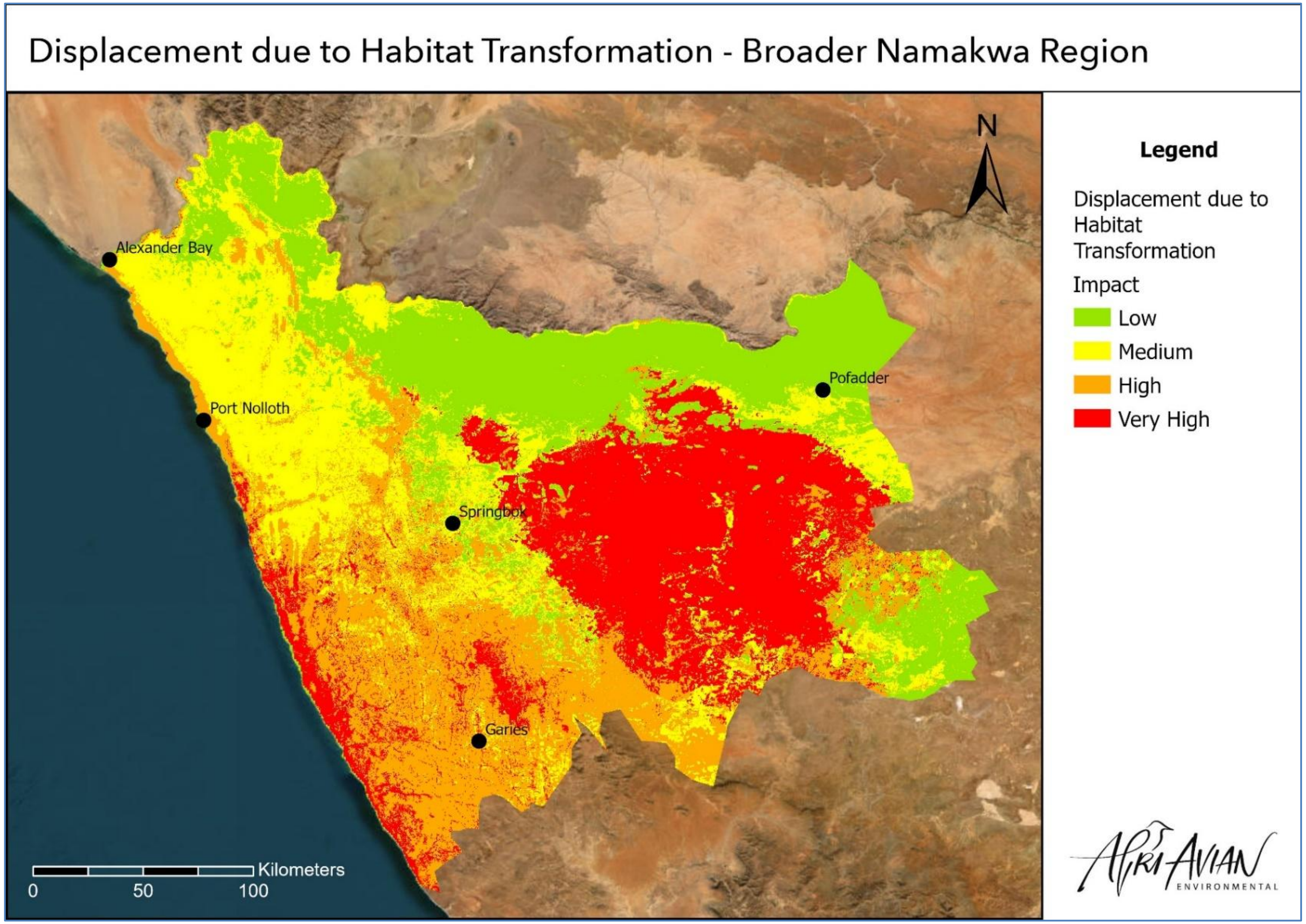

Figure 6: The avian sensitivity of the Namakwa Region generated from the weighted analysis incorporating the 44 priority avian species selected for this risk assessment as it relates to the potential impact of displacement due to habitat loss / fragmentation / transformation.

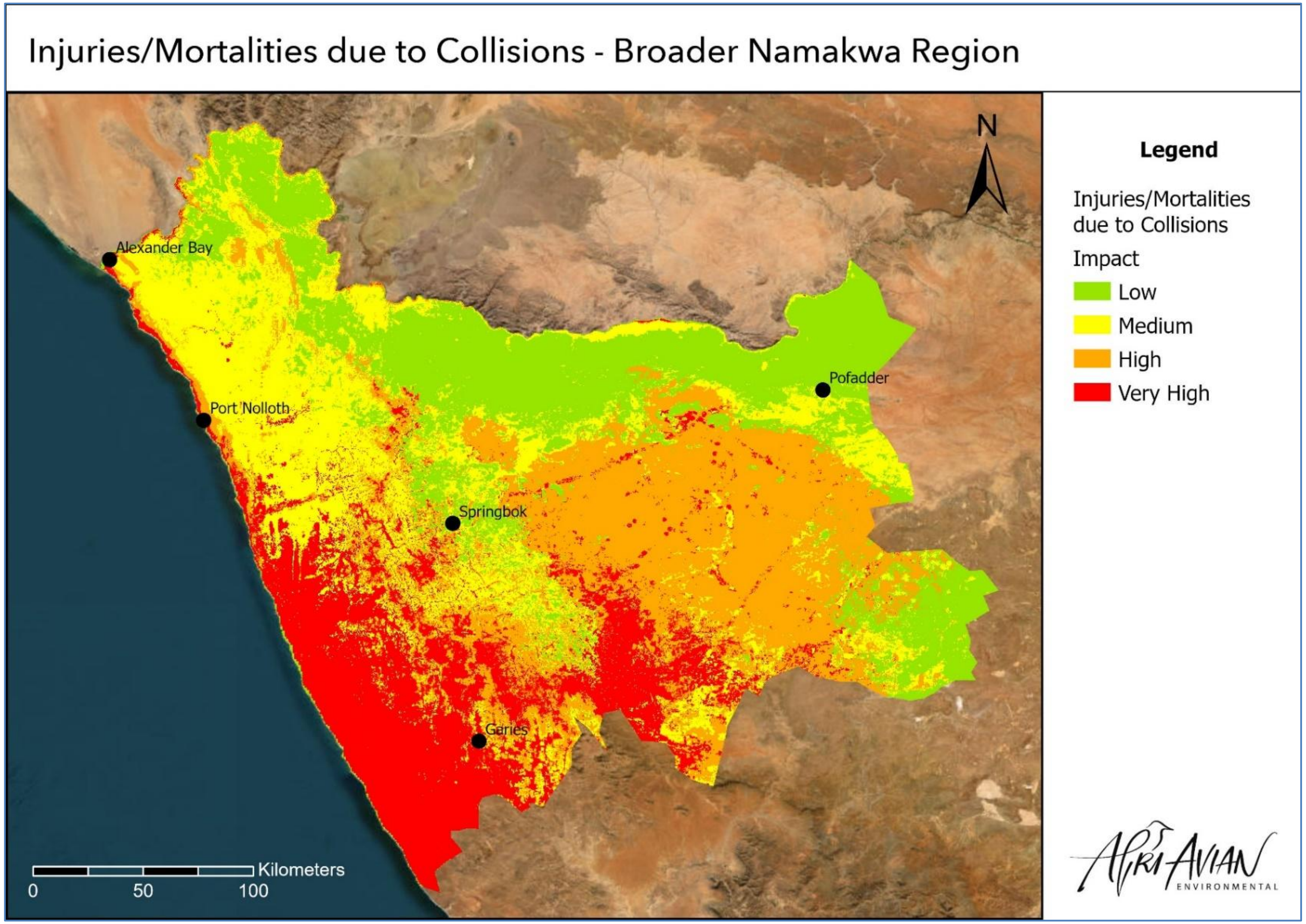

Figure 7: The avian sensitivity of the Namakwa Region generated from the weighted analysis incorporating the 44 priority avian species selected for this risk assessment as it relates to the potential impact of injuries or direct mortalities due to collisions.

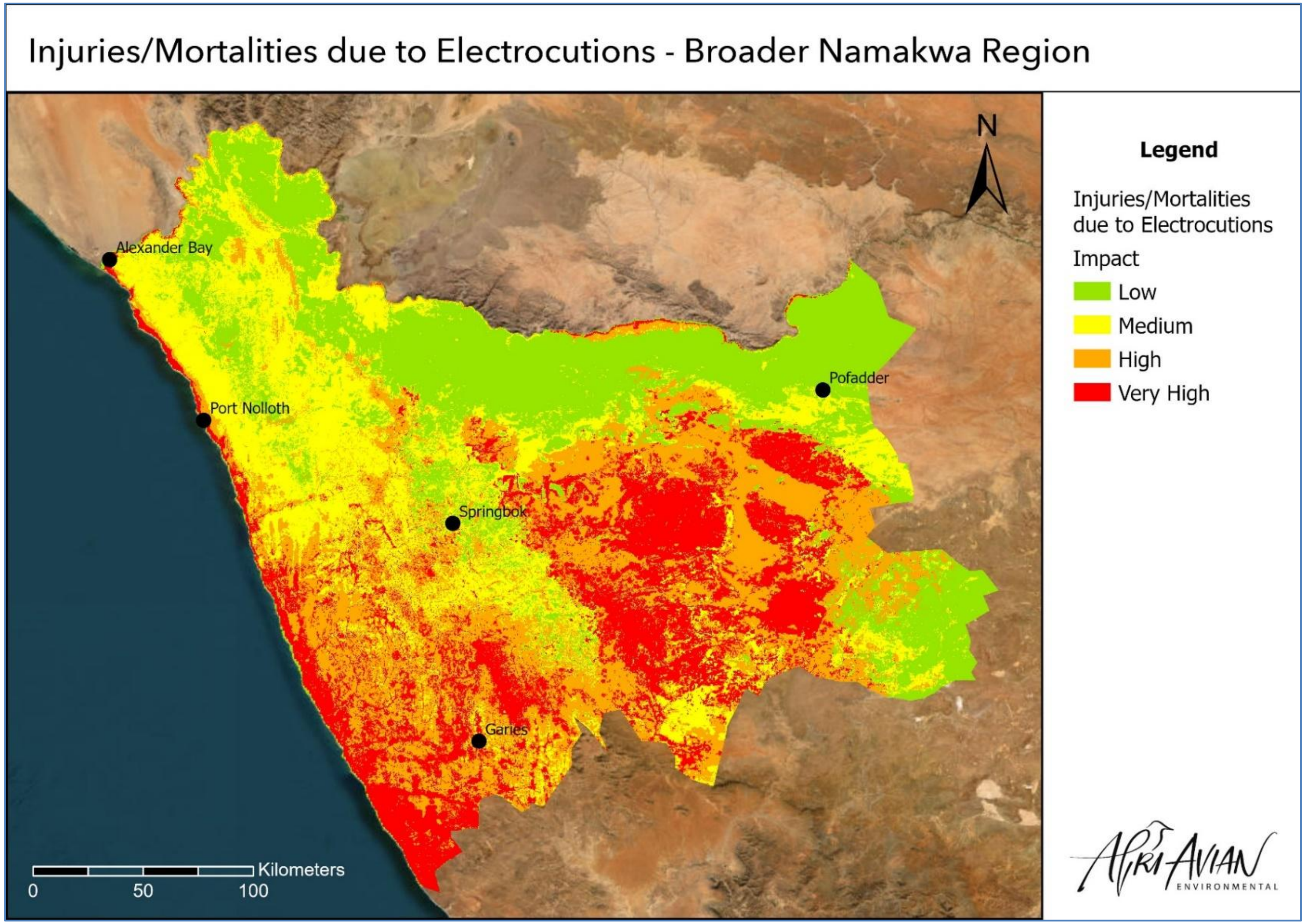

Figure 8: The avian sensitivity of the Namakwa Region generated from the weighted analysis incorporating the 44 priority avian species selected for this risk assessment as it relates to the potential impact of injuries or direct mortalities due to electrocutions.

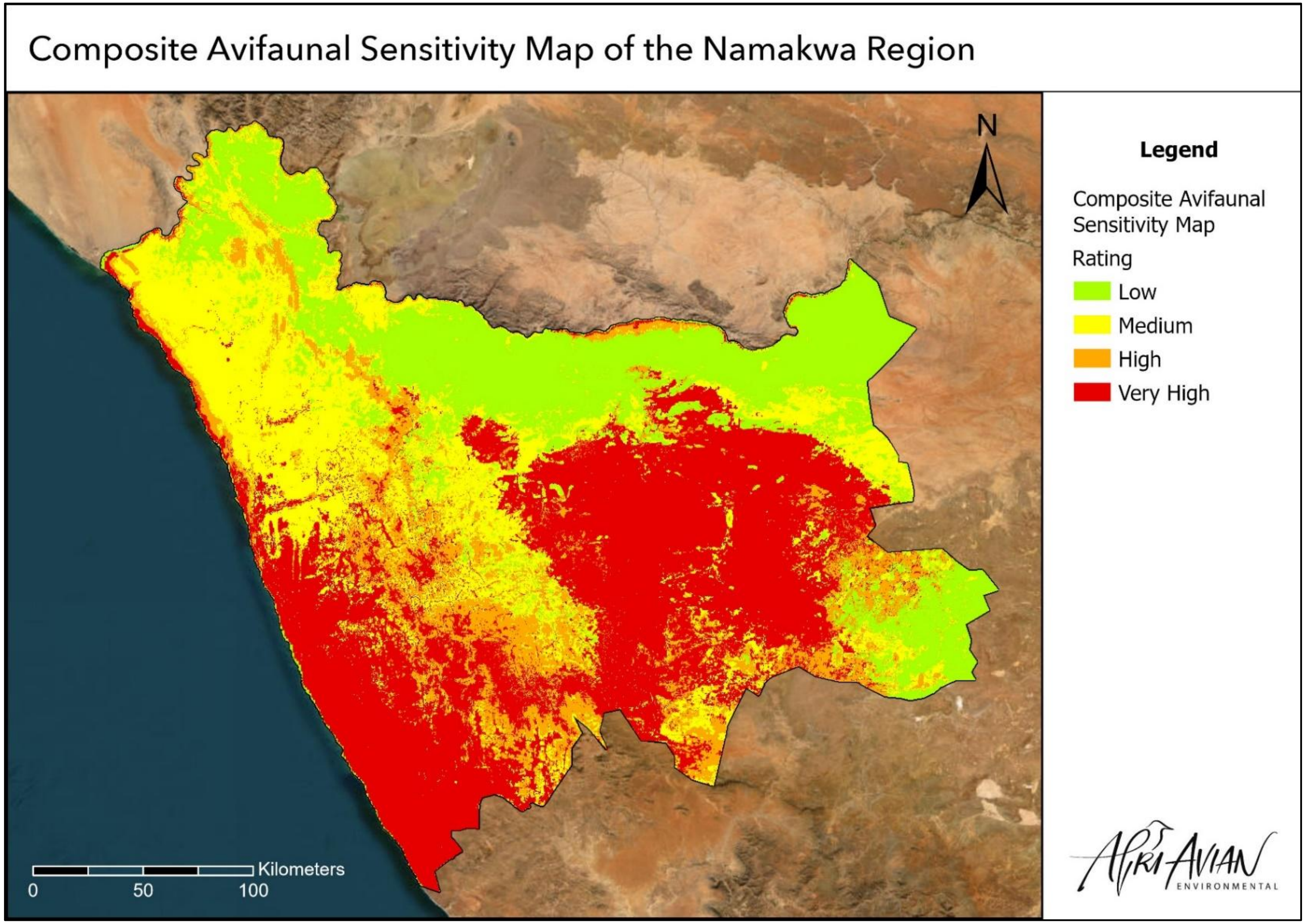

Figure 9: The composite avian sensitivity of the Namakwa Region generated from the weighted analysis incorporating the 44 priority avian species selected for this risk assessment considering all four primary sensitivity layers applying the maximum rule.

7. RISK ASSESSMENT

7.1 How Risk is Determined

In this SEA, risk is determined by evaluating the likelihood of an impact occurring and the potential effect or consequence of that impact on priority avifaunal species occurring in the Namakwa Region (**Figure**).

For this avifaunal specialist assessment, undertaken as part of WP2 of the SEA, the potential impacts to avifauna (i.e., habitat loss, disturbance, collision and electrocution risk) are considered to be negative (-) in nature. At present, no direct or indirect opportunities for avifauna have been identified or are predicted under the current proposed project design and mitigation framework. That said, built-in safeguards such as biodiversity offsets, conservation servitudes, set-asides, micro-siting and collision deterrents are known to reduce adverse effects but remain classified as negative unless they deliver measurable net gains (e.g., new breeding sites, quantified increases in functional avifaunal habitat, and evidence that gains outweigh residual losses). As such, potential indirect opportunities for avifauna can be stipulated at a project-by-project level to potentially achieve an overall no net loss.

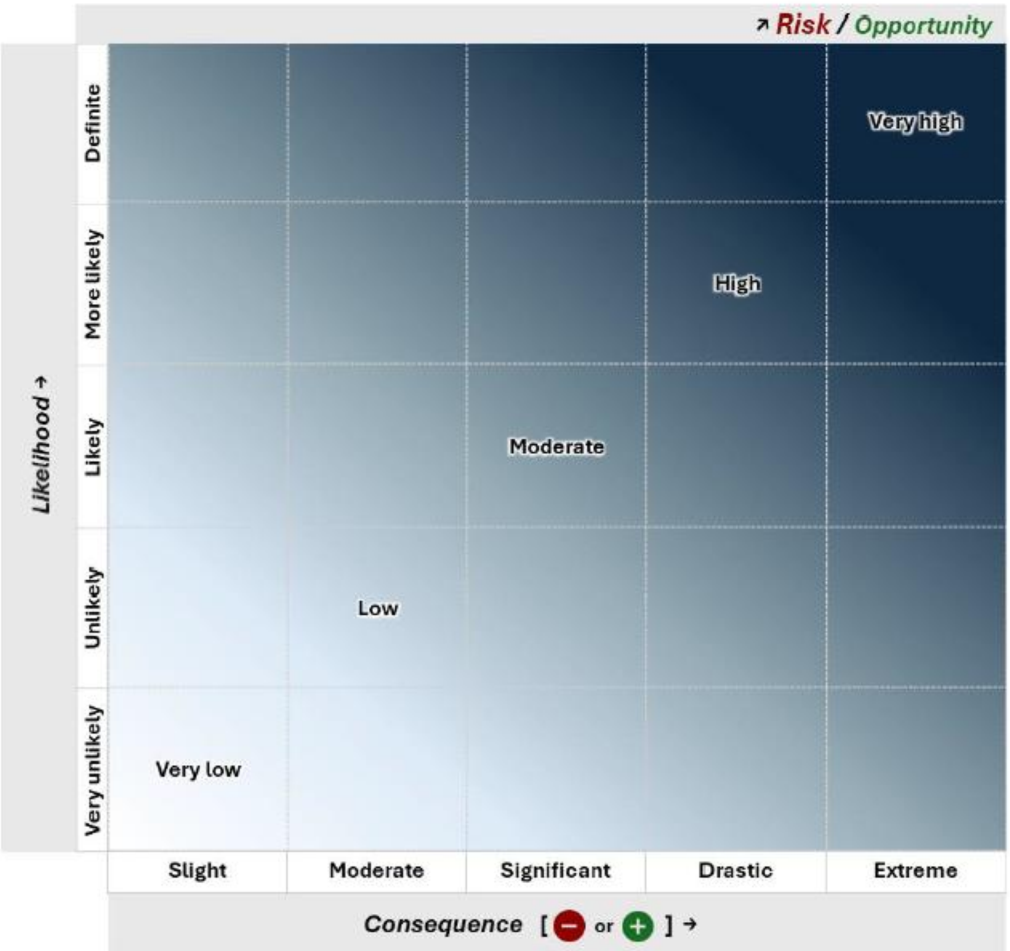

Figure 1: Risk and opportunity is qualitatively measured by multiplying the likelihood of an impact (negative or positive) by the severity of the consequence or benefit (Source: CSIR, 2025).

7.2 How Consequence is Determined

Consequence, also referred to as severity, refers to the potential outcome or effect if a risk or impact occurs. It is a key component in determining the overall level of risk and is assessed by evaluating the degree of harm or damage that could result.

In South African avifaunal specialist assessments, particularly those aligned with guidelines stipulated by BirdLife South Africa and Endangered Wildlife Trust, and in accordance with the Avifaunal Specialist Protocol (GNR 320 of 2020) in terms of the 2014 NEMA EIA Regulations (as amended) consequence thresholds are generally distinguished along a gradient of magnitude, extent, duration and reversibility of an impact occurring, and resultant conservation importance.

These consequence thresholds (**Table**) are often applied in impact significance matrices where consequence is combined with likelihood to determine overall significance ratings. For avifauna, the population viability context which include species' Red List status, range size, generation length and sensitivity to the impact mechanism, is central to assigning the correct threshold.

Table 4: Consequence thresholds defined for determining potential risk of impact to avifauna within the Namakwa Region

Threshold	Consequence levels defined for impact on Avifauna
Slight	Negligible to very low magnitude; localised; short-term; fully reversible; no measurable effect on population viability; affects only common/non-threatened/non-target species.
Moderate	Low to medium magnitude; local or limited regional extent; short- to medium-term; reversible with mitigation; may cause minor, non-sustained reductions in local abundance but no long-term viability risk.
Substantial	Medium magnitude; regional extent or affecting key habitats; medium- to long-term; partially reversible; measurable reduction in local population size or productivity; medium risk to one or more avifaunal species of conservation concern (Endemic and Near-Endemic species) but unlikely to threaten overall population persistence.
Severe	High magnitude; regional to national extent; long-term or permanent; largely irreversible; substantial reduction in population size or productivity; high risk to one or more avifaunal species of conservation concern (Vulnerable and Near-Threatened species) potentially affecting viability of local or metapopulations.
Extreme	Very high magnitude; national or global extent; permanent and irreversible; threatens survival of Endangered and Critically Endangered avifaunal species or leads to local extinction; affects critical habitats for Endangered and Critically Endangered avifaunal species.

7.3 How Risk Categories are Defined

Risk to avifauna in the Namakwa Region is assessed for each identified impact (see Section 3), considering the different types of avifaunal habitat characteristic of the study area (as described in Section 6.1), and incorporating the 44 priority avian species selected for this risk assessment (see Section 6.2), qualitatively against a predefined set of sensitivity criteria as described in Section 6.4 above. **Table** outlines the predefined risk categories utilised in this avifaunal risk assessment.

Table 5: Predefined risk categories applicable to the Avifaunal Risk Assessment for this SEA (Source: CSIR, 2025)

Risk (-) level	Category description
VERY LOW	Almost indiscernible negative impact
LOW	Slight negative impact, limited extent, and short duration, well within tolerance levels
MODERATE	Substantial impact, but less than major; within tolerance levels and below limits of acceptable change
HIGH	Major consequences, approaching tolerance and limits of acceptable change
VERY HIGH	Extremely negative impact, persistent/long lasting impact, beyond tolerance and limits of acceptable change

7.4 Risk Assessment with and without Mitigation

Table 6 shows the risk associated with the potential negative (-) impacts to priority avifaunal species determined for each development scenario: S0: Baseline Scenario, S1: Small scale GH_2 development, and S2: Big scale GH_2 development, for each sensitivity criteria, both with and without mitigation management.

It is important to note that the precautionary approach was exercised when following this risk assessment methodology and determining the risk associated with the potential negative (-) impacts to priority avifaunal species within the Namakwa Region.

1 **Table 6:** Risk Assessment determined for negative impacts to Avifauna within the Namakwa Region for each proposed GH_2 development scenario

Negative (-) impact	Development Scenario	Spatial receiving environment / receptor	Without management/mitigation			With management/mitigation		
			Consequence (-)	Likelihood	Risk	Consequence (-)	Likelihood	Risk
Displacement due to disturbance such as noise, lighting and human activity	S0: BASELINE	Very High Sensitivity	Substantial	Likely	Moderate	Moderate	Likely	Moderate
	S1: SMALL GH_2		Substantial	Definitive	Very High	Moderate	More likely	High
	S2: BIG GH_2		Severe	Definitive	Very High	Substantial	More likely	High
	S0: BASELINE	High Sensitivity	Moderate	Likely	Moderate	Slight	Likely	Moderate
	S1: SMALL GH_2		Substantial	More likely	High	Moderate	Likely	Moderate
	S2: BIG GH_2		Severe	Definitive	Very High	Substantial	More likely	High
	S0: BASELINE	Medium Sensitivity	Moderate	Likely	Moderate	Slight	Unlikely	Low
	S1: SMALL GH_2		Moderate	More likely	High	Slight	Likely	Moderate
	S2: BIG GH_2		Substantial	More likely	High	Moderate	Likely	Moderate
	S0: BASELINE	Low Sensitivity	Moderate	Likely	Moderate	Slight	Very unlikely	Very Low
	S1: SMALL GH_2		Moderate	More likely	High	Slight	Likely	Moderate
	S2: BIG GH_2		Substantial	More likely	High	Moderate	Likely	Moderate
Displacement due to Habitat loss/ fragmentation/ transformation	S0: BASELINE	Very High Sensitivity	Substantial	Likely	Moderate	Moderate	Likely	Moderate
	S1: SMALL GH_2		Extreme	Definitive	Very High	Severe	More likely	High
	S2: BIG GH_2		Extreme	Definitive	Very High	Severe	Definitive	Very High
	S0: BASELINE	High Sensitivity	Substantial	Likely	Moderate	Moderate	Likely	Moderate
	S1: SMALL GH_2		Severe	More likely	High	Substantial	More likely	High
	S2: BIG GH_2		Extreme	Definitive	Very High	Severe	Definitive	Very High
	S0: BASELINE	Medium Sensitivity	Substantial	Likely	Moderate	Moderate	Likely	Moderate
	S1: SMALL GH_2		Substantial	More likely	High	Moderate	Likely	Moderate
	S2: BIG GH_2		Severe	Definitive	Very High	Substantial	More likely	High
	S0: BASELINE	Low Sensitivity	Moderate	Unlikely	Low	Slight	Unlikely	Low
	S1: SMALL GH_2		Substantial	More likely	High	Moderate	Likely	Moderate
	S2: BIG GH_2		Substantial	Definitive	Very High	Substantial	More likely	High
Injury or mortality due to	S0: BASELINE	Very High Sensitivity	Substantial	Likely	Moderate	Moderate	Likely	Moderate

Negative (-) impact	Development Scenario	Spatial receiving environment / receptor	Without management/mitigation			With management/mitigation		
			Consequence (-)	Likelihood	Risk	Consequence (-)	Likelihood	Risk
collisions with wind turbines, solar panels, powerlines and masts/towers	S1: SMALL GH_2		Extreme	Definitive	Very High	Severe	More likely	High
	S2: BIG GH_2		Extreme	Definitive	Very High	Extreme	More likely	Very High
	S0: BASELINE	High Sensitivity	Substantial	Likely	Moderate	Moderate	Unlikely	Low
	S1: SMALL GH_2		Severe	More likely	High	Substantial	Likely	Moderate
	S2: BIG GH_2		Extreme	Definitive	Very High	Severe	Likely	High
	S0: BASELINE	Medium Sensitivity	Moderate	Likely	Moderate	Slight	Unlikely	Low
	S1: SMALL GH_2		Severe	More likely	High	Moderate	Likely	Moderate
	S2: BIG GH_2		Severe	More likely	High	Substantial	Likely	Moderate
	S0: BASELINE	Low Sensitivity	Moderate	Unlikely	Low	Slight	Very unlikely	Very Low
	S1: SMALL GH_2		Substantial	Likely	Moderate	Moderate	Very unlikely	Low
	S2: BIG GH_2		Substantial	More likely	High	Moderate	Likely	Moderate
Injury or mortality due to electrocution on powerlines and substation infrastructure	S0: BASELINE	Very High Sensitivity	Severe	More likely	High	Substantial	Likely	Moderate
	S1: SMALL GH_2		Extreme	Definitive	Very High	Severe	More likely	High
	S2: BIG GH_2		Extreme	Definitive	Very High	Extreme	More likely	Very High
	S0: BASELINE	High Sensitivity	Severe	More likely	High	Substantial	Unlikely	Moderate
	S1: SMALL GH_2		Extreme	Definitive	Very High	Severe	Likely	High
	S2: BIG GH_2		Extreme	Definitive	Very High	Extreme	More likely	Very High
	S0: BASELINE	Medium Sensitivity	Substantial	Likely	Moderate	Moderate	Unlikely	Low
	S1: SMALL GH_2		Severe	More likely	High	Substantial	Unlikely	Moderate
	S2: BIG GH_2		Severe	More likely	High	Severe	Likely	High
	S0: BASELINE	Low Sensitivity	Moderate	Unlikely	Low	Slight	Very unlikely	Very Low
	S1: SMALL GH_2		Substantial	Likely	Moderate	Moderate	Unlikely	Low
	S2: BIG GH_2		Severe	Likely	High	Substantial	Likely	Moderate

7.5 Recommended Management Responses for Risk Categories

The sensitivity mapping and risk categories used only provides a broad, strategic overview of the relative suitability and potential for development within and across the Namakwa Region. Even in areas of low sensitivity it is important that some form of project-level environmental impact assessment be undertaken to confirm and refine the outputs as presented in this SEA.

Where relevant, it is critical that implementation of one and/or more of the following recommended best practice measures be considered for the effective mitigation and management of negative impacts to avifauna when GH_2-related development activities are proposed:

- Habitat management and restoration (by restoring indigenous vegetation, re-establishing natural hydrology, and reconnecting fragmented patches outside the development footprint, while actively removing or mitigating on-site attractants such as open water or livestock/wildlife carcasses, bird species are drawn away from areas where potential collision, entanglement or disturbance risks are greatest).

- Anti-perching devices on tall infrastructure (bird-friendly pylon designs, insulated electrical components, meteorological masts and communication towers).

- Bird flight diverters (powerlines).

- Livestock/game carcass removal management.

- Turbine design (including height of blade tip from the ground).

- Turbine layout (e.g. not perpendicular to flight paths).

- Turbine blade cut-in speed.

- Shutdown on Demand (observer-led and automated including cameras and radar).

- Proactive curtailment (diurnal and nocturnal).

- Blade patterning.

- Monitoring, mitigation and proactive conservation beyond the facility footprint.

8. RECOMMENDED STRATEGIC MANAGEMENT ACTIONS TO MINIMISE AVIFAUNAL IMPACTS IN REGIONAL PLANNING

A regional approach should embed avifaunal risk management into Environmental Management Frameworks (EMFs), Spatial Development Frameworks (SDFs), Integrated Development Plans (IDPs), and downstream project-level Environmental Impact Assessments (EIAs) and Environmental Management Programmes (EMPrs) by setting clear spatial priorities, technology standards, and adaptive management rules. EMFs and SDFs can define strategic sustainability objectives, indicators, and targets that guide land-use and infrastructure planning across municipal IDPs and sector plans, improving consistency and decision quality at the EIA stage.

8.1 Sensitivity Mapping and Spatial Controls

- *Tiered sensitivity layers:* Map ecological features such as KBAs [previously Important Bird Areas (IBAs)], Red List species' status and their ranges, known flyways, nests, roosts/colonies, wetlands/pans, shorelines and key foraging corridors, and then classify each as no-go, conditional / compatible or exclusion zones.

- *Buffers and setbacks:* Establish evidence-based buffers for wetlands, rivers, roosts/colonies, raptor and ground-dwelling species nests, coastal dunes, and pans (freshwater and saline). These buffers and setbacks require robust specialist motivation to deviate from.

- *Linear-infrastructure alignment:* Predefine preferred corridors for electricity grid, pipelines, roads, and rail to avoid high-risk avian areas and maintain landscape connectivity.

- *Cumulative "caps"*: Set development density/throughput thresholds for wind energy, solar energy, powerlines, GH_2 and port development within avian-sensitive landscapes to prevent cumulatively exceeding acceptable limits.

8.2 Mitigation Hierarchy and Policy Standards

- *Avoidance first*: Prioritise site screening to exclude high-risk features (e.g., vulture flight paths, crane breeding territories, tern islands, cormorant colonies).

- *Design optimisation*: Require technology-specific design standards (see Section 8.3 below) embedded as SDF/EMF overlays and standard EIA conditions.

- *Minimisation measures*: Implement recommended mitigation measures as included in the Environmental Management Programme (EMPr) for each proposed development application (see Section 7.5 above).

- *Offsets as last resort*: If residual impacts remain significant, apply like-for-like offsets with measurable, time-bound outcomes and independent verification (DFFE, 2023).

8.3 Technology-Specific Design Requirements

8.3.1 Wind Energy:

- *Siting controls:* Assign no-go buffers to critical habitat, key flight path corridors, nests and roosts/colonies, and apply micro-siting to avoid ridge saddles and thermalling zones.

- *Operational curtailment:* Mandatory automated/observer-based Shutdown-on-Demand protocols for high-risk wind priority species; implement seasonal curtailment where warranted.

- *Turbine specs:* Minimise hub-height/ rotor-diameter (shorter blade length) constraints to reduce risk of collision where species profiles support it.

8.3.2 Solar PV Energy:

- *Anti-attraction design:* Panel orientation/anti-reflective treatments; avoid "lake effect" near waterbird habitats.

- *Habitat retention:* Set aside vegetated corridors; manage fencing to permit small-fauna permeability, where safe.

8.3.3 Powerlines and Substations:

- *Collision mitigation:* High-performance (phosphorescent and staggered) bird flight diverters on high-risk spans; alignments parallel to topography and flyways to reduce crossings.

- *Electrocution mitigation:* Raptor-safe pole designs, adequate phase-conductor spacing, insulated jumpers, and perch guards where needed.

- *Substation aversion:* Netting and design to prevent perching/nesting in hazardous zones.

8.3.4 Masts and Towers:

- *Design/marking:* Minimise guyed masts; mark guy wires; use low-intensity, downward-shielded lighting.

- *Placement:* Avoid migratory corridors, wetlands, and ridgelines frequently used by soaring birds.

8.3.5 Roads, Rail and Pipelines:

- *Routing:* Avoid core/ critical habitats; maintain wetland hydrology with adequate culverts; minimise night works near breeding areas.

- *Operations:* Speed controls, carcass removal to deter scavenger activity, lighting management.

8.3.6 Desalination and Ports (where relevant):

- *Intakes/outfalls:* Low velocity screened intakes; offshore diffusers to protect prey bases; time construction to avoid breeding seasons.

- *Lighting and vessel traffic:* Shielded lighting; navigation protocols to reduce disturbance and strike risk.

8.4 Monitoring, Thresholds and Adaptive Management

- *Standardised monitoring:* Pre- and post-construction monitoring must follow consistent, defensible protocols, including systematic carcass searches with appropriate correction factors, carcass persistence and searcher efficiency trials, and standardised vantage point or activity budget surveys where relevant. All monitoring outputs should be integrated into municipal or regional data repositories to support cumulative impact tracking.

- *Thresholds of potential concern (TPCs):* Species- and site-specific trigger levels should be defined for collision rates, displacement indices, breeding success, and fatality thresholds. Exceedance of TPCs must automatically trigger corrective or adaptive management actions during construction and operations.

- *Adaptive responses:* A graduated suite of responses should be available when TPCs are exceeded, including enhanced line marking or bird flight diverters, additional curtailment windows, route adjustments for linear infrastructure, targeted habitat management, and intensified monitoring protocols.

- *Population context:* Monitoring results should be interpreted in relation to Potential Biological Removal (PBR) thresholds and, where data allow, Population Viability Analysis (PVA) for priority species. Development pacing and operational mitigation should be adjusted if cumulative risk approaches viability thresholds.

- *Environmental and logistical constraints to post-construction monitoring:* Post-construction fatality monitoring in the Namakwa Region may be constrained by several environmental and access-related factors that must be explicitly acknowledged in monitoring plans. Monitoring protocols should therefore be adapted to local conditions, with transparent documentation of limitations and the application of conservative correction factors where uncertainty is high –

- **Low carcass persistence** due to scavenger communities (jackals, corvids, raptors) may reduce detectability and require higher search frequencies or more intensive correction trials.
- **Challenging terrain and accessibility**, including rocky substrates, steep slopes, and remote turbine or transmission tower/line locations, may limit the feasibility of standardised transect searches and necessitate modified search designs.
- **Vegetation structure** (e.g., low shrubs, patchy cover) may influence detectability and require site-specific calibration of searcher efficiency.
- **Extreme weather conditions** (heat, wind, dust) may affect both carcass persistence and observer performance, requiring seasonal adjustments to monitoring intensity.
- **Safety and access restrictions** on private or mining-related land parcels may limit search coverage and require negotiated access agreements.
- **Remoteness and logistical constraints**: The Namakwa Region is vast, sparsely populated, and characterised by long travel distances between infrastructure sites. Deploying search teams is therefore time-consuming and costly, often requiring multi-day field trips, specialised vehicles, and careful scheduling to ensure adequate coverage. These logistical realities may limit search frequency and necessitate adaptive sampling designs, conservative correction factors, and transparent documentation of effort.

- *Species and area specific monitoring priorities:* Beyond standard monitoring requirements, certain species and landscape features in the Namakwa Region warrant enhanced or targeted monitoring due to their conservation status, mobility, or sensitivity to infrastructure. These enhanced monitoring requirements ensure that species with limited baseline data, high collision susceptibility, or regionally important populations are adequately assessed and that adaptive management is informed by the best available evidence –
  - **Large raptors (e.g., Vultures, Martial Eagle, Verreaux's Eagle):**
    - targeted collision-risk monitoring at turbines and transmission lines;
    - monitoring of known or potential roosts, nests, and foraging hotspots;
    - engagement with organisations such as VulPro and EWT to integrate rehabilitation and incidental observation data.
  - **Large terrestrial birds (e.g., Ludwig's Bustard, Kori Bustard, Blue Crane, Secretarybird):**
    - seasonal movement monitoring to detect shifts in habitat use;
    - targeted collision monitoring along transmission corridors and in topographic "funnel" areas.
  - **Wetland-associated species (e.g., flamingos, waterbirds):**
    - monitoring at ephemeral pans, estuaries, and inland wetlands where CWAC data indicate periodic high use;
    - assessment of disturbance or displacement linked to construction activity or increased traffic.
  - **High-risk landscape features:**
    - topographic ridgelines, escarpment edges, and valley funnels that concentrate flight paths;
    - areas adjacent to known breeding territories or communal roosts;
    - wetland or pan complexes that attract seasonal aggregations.

8.5 Governance, Permitting, and Data Management

- *Standard conditions:* Include avifaunal design standards and fatality monitoring, construction method statements, seasonal constraints, and independent Environmental Control Officer (ECO) oversight in approvals.

- *Cumulative reviews:* Require project-level EIAs to assess cumulative effects against EMF/SDF caps and regional monitoring data, not only project-alone impacts.

- *Open data:* Mandate submission of monitoring datasets (incl. GenEst[5] inputs/outputs) to a provincial repository to inform ongoing planning.

- *Capacity and coordination:* Establish a regional avifaunal technical forum (municipality, conservation NGOs, grid operators, developers) to review data and recommend adaptive policy updates.

8.6 Incentives and Financing

- *Performance-based approvals:* Fast-track low-risk sites and designs meeting gold-standard avifaunal criteria.

- *Mitigation funding:* Create a regional levy or biodiversity fund for retrofitting legacy powerlines, securing buffer habitats, and managing predator control where appropriate.

9. CONCLUSIONS AND RECOMMENDATIONS

The Namakwa Region, located mostly within the Succulent Karoo Biodiversity Hotspot, is of exceptional avifaunal importance and contains 15 Key Biodiversity Areas crucial for many threatened, endemic and range restricted avifaunal species. Spatial sensitivity mapping confirms extensive Very High and High avian sensitivity zones across the study area, particularly for wind farm related impacts.

The risk assessment shows that without mitigation, both Small GH_2 and Big GH_2 development scenarios present High to Very High risks to priority avifaunal species, especially in very high sensitivity areas. The Big GH_2 scenario carries the greatest cumulative risk, with potential severe to extreme consequences for Endangered and Critically Endangered species. Even with best practice mitigation, residual impacts remain substantial in habitats, especially high and very high sensitivity for the priority avifaunal species assessed.

Key impact pathways relating to priority avifauna include:

- Displacement from disturbance and habitat loss/fragmentation.
- Collisions with wind turbines, powerlines, and other tall structures.
- Electrocutions on transmission and distribution infrastructure.

The Namakwa Region's exceptional avifaunal diversity faces substantial risk from large scale GH_2 and associated infrastructure development given the scale of the proposed infrastructure required. Strategic avoidance of high and very high sensitivity areas, rigorous application of the mitigation hierarchy, and the implementation of robust monitoring frameworks are essential to balance renewable energy ambitions, associated with the GH_2 development proposal for the Boegoebaai Port and SEZ, with biodiversity

[5] A Generalized Estimator of Mortality is a free, open-source statistical model and software tool, most notably named GenEst, that is used to accurately estimate the total number of wildlife (bird) fatalities in a specific area, particularly at facilities like wind or solar farms, especially when not all mortalities are directly observed and where discovery probability is less than one (https://www.usgs.gov/software/genest-a-generalized-estimator-mortality).

conservation in the broader Namakwa Region. The SEA and this avifaunal risk assessment therefore provide a defensible, spatially explicit framework to guide sustainable regional planning for development and safeguard irreplaceable bird populations.

Key recommended strategic management actions resulting from this avifaunal risk assessment include:

1. Spatial Planning & Sensitivity Controls

Embed avifaunal sensitivity mapping into planning tools (such as EMFs, SDFs, IDPs), designate no-go zones for critical habitats, apply science-based buffers, align infrastructure to avoid very high and high-risk areas, and cap cumulative development in sensitive landscapes.

2. Technology-Specific Standards

Adopt bird-safe design and operational mitigation measures for wind, solar, powerlines, masts, and port/desalination facilities to minimise collisions, electrocution, and disturbance risks through siting, engineering, and seasonal restrictions.

3. Monitoring & Adaptive Management

Use standardised pre- and post-construction monitoring protocols with GenEst[6], set Thresholds of Potential Concern (TPCs), link results to Potential Biological Removal (PBR) rates and Population Viability Analysis (PVA), and trigger adaptive measures when thresholds are exceeded.

4. Governance & Data Management

Mandate avifaunal standards and independent oversight in approvals, require cumulative impact reviews, ensure open data sharing, and establish a regional technical forum for coordinated decision-making.

5. Incentives & Financing

Fast-track low-risk, high-standard projects and fund biodiversity actions, such as retrofitting hazardous infrastructure and securing key habitats, through a dedicated conservation fund.

[6] A Generalized Estimator of Mortality is a free, open-source statistical model and software tool, most notably named GenEst, that is used to accurately estimate the total number of wildlife (bird) fatalities in a specific area, particularly at facilities like wind or solar farms, especially when not all mortalities are directly observed and where discovery probability is less than one (https://www.usgs.gov/software/genest-a-generalized-estimator-mortality).

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11. ANNEXURE A

ANNEXURE A: Table detailing the species-impact scoring framework that defines the sensitivity categories underpinning the multiplicative weighting system used to enable the spatial risk mapping for this avifaunal specialist assessment—see Section 6.4 to Section 6.6 for a detailed description.

Priority Species Name	Red Data List 2025	Endemism 2025	Habitat_area_hectares	Species_range	Red_Data_multiplier	Range_multiplier	Endemism_multiplier	Conservation_multiplier	Displacement - Disturbance	Displacement_disturbance_ weighted_score	Displacement due to Habitat Loss/Transformation	Displacement_habitat_ weighted_score	Collisions turbines and infrastructure	Collisions_weighted_score	Electrocutions	Electrocutions_weighted_score
Jackal Buzzard		NE	4549885	Large	1	1	3	3	1	3	2	6	4	12	3	9
Ludwig's Bustard	EN		4431321	Large	8	1	1	8	2	16	3	24	4	32	1	8
Karoo Eremomela		NE	3480362	Medium	1	5	3	15	1	15	2	30	1	15	1	15
Black-headed Canary		NE	3477791	Medium	1	5	3	15	1	15	2	30	2	30	1	15
Black Harrier	EN	NE	2541556	Medium	8	5	3	120	2	240	3	360	4	480	1	120
Karoo Korhaan	NT		2223362	Large	2	1	1	2	1	2	2	4	4	8	1	2
Black-eared Sparrow-Lark		NE	1969719	Medium	1	5	3	15	1	15	3	45	1	15	1	15
Burchell's Courser	VU		1899542	Medium	4	5	1	20	1	20	3	60	2	40	1	20
Secretarybird	EN		1730344	Medium	8	5	1	40	2	80	3	120	3	120	2	80
Cape Clapper Lark		NE	1257024	Medium	1	5	3	15	1	15	3	45	1	15	1	15
Red Lark	VU	E	1255419	Small	4	10	5	200	2	400	4	800	3	600	1	200
Lanner Falcon	NT		1202044	Large	2	1	1	2	1	2	2	4	4	8	2	4
Cape Eagle-Owl			1063543	Medium	1	5	1	5	2	10	3	15	3	15	2	10
Sclater's Lark	NT	NE	994121	Medium	2	5	3	30	2	60	3	90	1	30	1	30
Southern Black Korhaan	VU	E	876964	Medium	4	5	5	100	1	100	2	200	4	400	1	100

Priority Species Name	Red Data List 2025	Endemism 2025	Habitat_area_hectares	Species_range	Red_Data_multiplier	Range_multiplier	Endemism_multiplier	Conservation_multiplier	Displacement - Disturbance	Displacement_disturbance_ weighted_score	Displacement due to Habitat Loss/Transformation	Displacement_habitat_ weighted_score	Collisions turbines and infrastructure	Collisions_weighted_score	Electrocutions	Electrocutions_weighted_score
Verreaux's Eagle	VU		681532	Large	4	1	1	4	1	4	2	8	4	16	4	16
Cinnamon-breasted Warbler		NE	648753	Medium	1	5	3	15	2	30	3	45	1	15	1	15
Cape Spurfowl		NE	647396	Medium	1	5	3	15	1	15	2	30	2	30	1	15
Ground Woodpecker	NT	SLS	614111	Medium	2	5	5	50	2	100	3	150	1	50	1	50
Martial Eagle	EN		522475	Large	8	1	1	8	1	8	2	16	4	32	4	32
Cape Long-billed Lark		E	500163	Medium	1	5	5	25	1	25	3	75	1	25	1	25
African Fish Eagle			339981	Large	1	1	1	1	1	1	2	2	3	3	2	2
Black Harrier	EN	NE	267195	Medium	8	5	3	120	2	240	3	360	4	480	1	120
Cape Rock Thrush		SLS	202608	Large	1	1	5	5	1	5	3	15	1	5	1	5
Grey-winged Francolin		SLS	183958	Medium	1	5	5	25	1	25	3	75	2	50	1	25
Maccoa Duck	EN		148242	Medium	8	5	1	40	1	40	2	80	2	80	1	40
African Rock Pipit	NT	SLS	143003	Medium	2	5	5	50	1	50	2	100	2	100	1	50
Blue Crane	VU		131653	Medium	4	5	1	20	2	40	3	60	4	80	1	20
Greater Flamingo	NT		129414	Large	2	1	1	2	2	4	3	6	4	8	1	2
Curlew Sandpiper	VU		105250	Medium	4	5	1	20	1	20	2	40	1	20	1	20
Caspian Tern	VU		73302	Large	4	1	1	4	1	4	2	8	2	8	1	4
Peregrine Falcon			66138	Large	1	1	1	1	1	1	2	2	4	4	2	2
Black Stork	EN		60809	Medium	8	5	1	40	2	80	2	80	4	160	2	80
Sentinel Rock Thrush	NT	SLS	39864	Medium	2	5	5	50	1	50	3	150	1	50	1	50

Priority Species Name	Red Data List 2025	Endemism 2025	Habitat_area_hectares	Species_range	Red_Data_multiplier	Range_multiplier	Endemism_multiplier	Conservation_multiplier	Displacement - Disturbance	Displacement_disturbance_ weighted_score	Displacement due to Habitat Loss/Transformation	Displacement_habitat_ weighted_score	Collisions turbines and infrastructure	Collisions_weighted_score	Electrocutions	Electrocutions_weighted_score
Damara Tern	EN		32984	Small	8	10	1	80	1	80	2	160	2	160	1	80
African Marsh Harrier	VU		30611	Medium	4	5	1	20	2	40	3	60	3	60	1	20
Great White Pelican	VU		30565	Medium	4	5	1	20	1	20	2	40	3	60	3	60
Black Stork	EN		26412	Medium	8	5	1	40	2	80	2	80	4	160	2	80
Bateleur	EN		23835	Small	8	10	1	80	2	160	2	160	3	240	3	240
Barlow's Lark			20149	Small	1	10	1	10	1	10	3	30	1	10	1	10
Chestnut-banded Plover	VU		15181	Medium	4	5	1	20	1	20	3	60	1	20	1	20
Cape Vulture	VU		10238	Large	4	1	1	4	1	4	2	8	4	16	4	16
Cape Sugarbird		E	8336	Medium	1	5	5	25	1	25	3	75	1	25	1	25
Orange-breasted Sunbird		E	5151	Medium	1	5	5	25	1	25	3	75	1	25	1	25