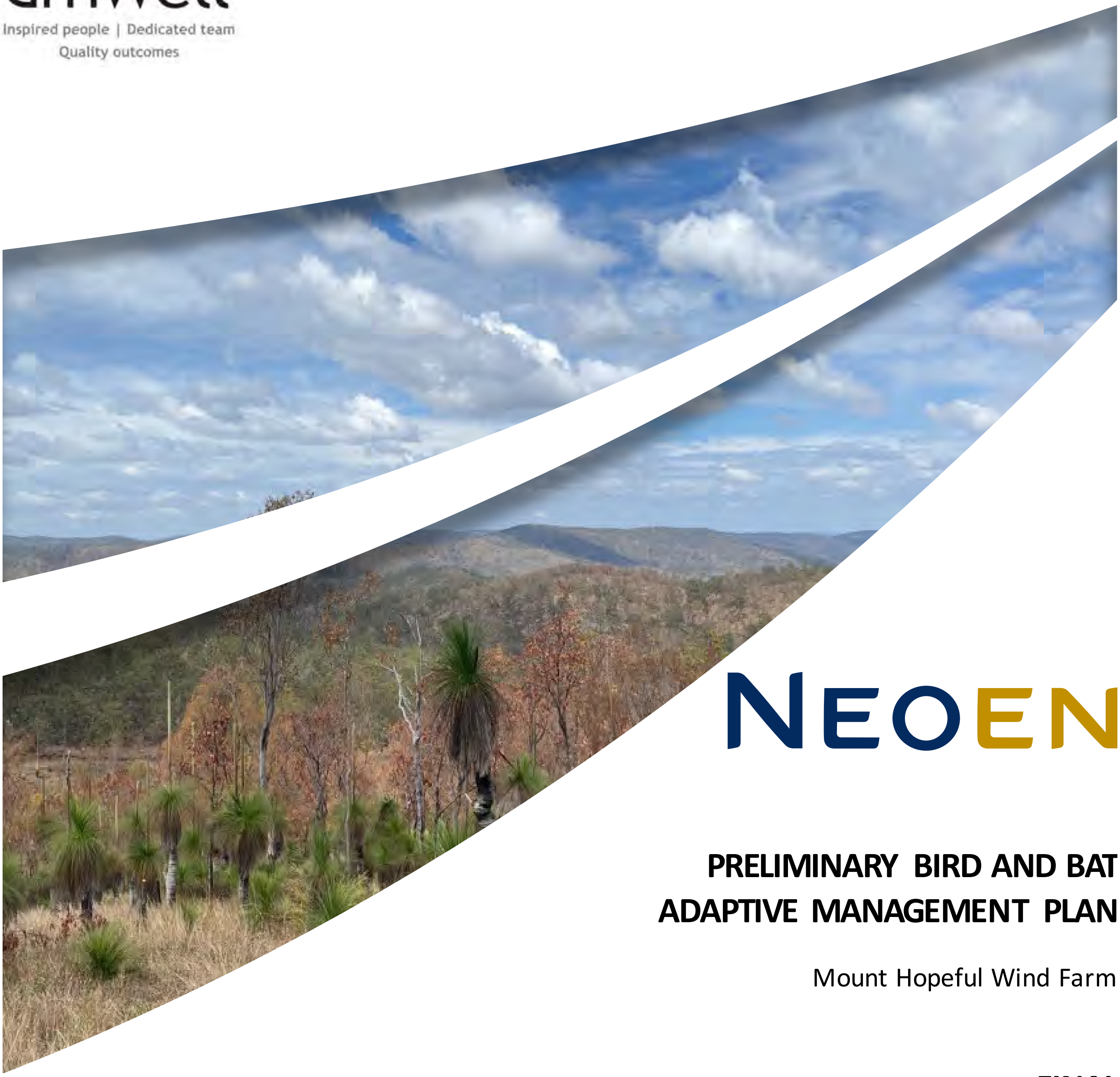

PRELIMINARY BIRD AND BAT ADAPTIVE MANAGEMENT PLAN

Mount Hopeful Wind Farm

FINAL

November 2023

PRELIMINARY BIRD AND BAT ADAPTIVE MANAGEMENT PLAN

Mount Hopeful Wind Farm

FINAL

Prepared by
Umwelt (Australia) Pty Limited
on behalf of
Neoen Australia Pty Ltd

Report No. 22753/R07
Date: November 2023

umwelt
Environmental & Social Consultants

This report was prepared using Umwelt's ISO 9001 certified Quality Management System.

Acknowledgement of Country

Umwelt would like to acknowledge the traditional custodians of the country on which we work and pay respect to their cultural heritage, beliefs, and continuing relationship with the land. We pay our respect to the Elders – past, present, and future.

Abbreviations

Abbreviations	Description
AHD	Australian Height Datum
BBAMP	Bird and Bat Adaptive Management Plan
BBUS	Bird and Bat Utilisation Survey
BBUA	Bird and Bat Utilisation Assessment
BESS	battery Energy Storage Systems
Biosis	Biosis Pty Ltd
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DES	Department of Environment and Science
EO Act	Environmental Offsets Act
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cth)
ha	hectare
km	kilometres
Km/h	Kilometres per hour
LGA	Local Government Areas
MW	megawatts
NC Act	*Nature Conservation Act 1992* (Qld)
Neoen	Neoen Australia Pty Ltd
PO	Performance Outcome
RFI	Request For Information
rpm	rotations per minute
the Project	Mount Hopeful Wind Farm
Umwelt	Umwelt (Australia) Pty Ltd
WTG	wind turbine generators

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Appendices

Appendix A	Bird and Bat Utilisation Assessment (Umwelt 2021)
Appendix B	Mount Hopeful Wind Farm Turbine Collision Risk Assessment for White-throated Needletail (Biosis, 2022)

1.0 Introduction

Umwelt is supporting Neoen Australia Pty Ltd (Neoen) in seeking project approvals for the Mount Hopeful Wind Farm (the Project). The Project is located approximately 45 kilometres (km) south of Rockhampton and 65 km west of Gladstone, within the Central Queensland Region.

This Preliminary Bird and Bat Adaptive Management Plan (BBAMP) seeks to support the Project's Preliminary Documentation for approval under the Commonwealth *Environment Protection and Biodiversity Act 1999* (EPBC Act) and provide an overview of the management and mitigation of risks to bird and bat species occurring within the Project.

This BBAMP has been informed by pre-commissioning surveys (completed between July 2019 and February 2022), as well as bird and bat data collected as part of the baseline ecology assessment.

1.1 Purpose and Relationship with State Approval

The purpose of this Preliminary BBAMP is to provide the Project framework regarding the adaptive management of potential impacts, attributable to the operation of the project, to birds and bats. Specifically, this Preliminary BBAMP has been prepared to address a Request For Information (RFI) from the Department of Climate Change, Energy, the Environment and Water (DCCEEW). As such, threatened bird and bat species listed under the Queensland, *Nature Conservation Act 1992* (NC Act) are excluded.

Following the finalisation of Project design, and prior to operation, a Project BBAMP which addresses both the Commonwealth and State approval requirements will be prepared, including impacts to threatened, migratory and non-threatened species.

1.2 Aims and Objectives

This Preliminary BBAMP seeks to provide an overview of the mitigation and management procedures undertaken at the Mount Hopeful Wind Farm to minimise the potential risks to EPBC Act listed bird and bat species. In achieving this, the following objectives have been prepared:

- Provide an overview of pre-commissioning survey results for the Project.
- Present the outcomes of the collision risk assessment, focussing on species which were deemed a high or very high risk of collision impacts.
- Present an overview of post-commissioning survey requirements including further bird and bat utilisation survey, as well as a carcass detection program.
- Provide proposed impact trigger thresholds for EPBC Act listed threatened and migratory species.
- Present the adaptive management framework to be initiated in the event that a trigger threshold is reached or exceeded.
- Outline ongoing and preventative mitigation and management measures, as well as reporting requirements.
- Continue to develop the understanding of the impacts to birds and bats associated with the construction and operation of the Project by assessing pre and post commissioning bird and bat data.

1.3 Project Description

The Mount Hopeful Wind Farm is located on the Ulam Range approximately 45 km south of Rockhampton, Queensland (Qld) and 65 km west of Gladstone, Qld.

The Project involves the development of a wind farm that contains 63 wind turbine generators (WTGs, turbines), ancillary infrastructure including up to ten temporary and ten permanent wind monitoring masts, six substations, battery energy storage systems (BESS), temporary construction compound/laydown areas, a concrete batching plant, high voltage (275 kilovolt (kV)) overhead powerlines, as well as underground power and communication cables. The Project includes a road access corridor which would involve upgrades to approximately 30 km of existing road between the Burnett Highway at Dixalea and Glengowan Road to ensure the safe transport of Project infrastructure. The Project is expected to have a maximum generation capacity of approximately 400 megawatts (MW).

At this stage in the Project, turbine specifications have not been confirmed by Neoen, however, the bird and bat utilisation assessment (**Appendix A**) used the following specifications to inform the assessment:

- a maximum overall height (tip height) of 260 metres (m) above ground level (AGL)
- a three-blade rotor with maximum blade length of 90 m
- a maximum hub height of 180 m AGL
- a rotor swept area (RSA) of between 55 m and 260 m AGL.

The collision risk modelling undertaken by Biosis (2022) used indicative turbine specifications based on two potential options including:

- Turbine A (RSA between 85 m and 247 m).
- Turbine B (RSA 66 m and 230 m).

A more detailed summary of turbines considered in the collision risk modelling is provided in **Section 4.2.1**.

1.3.1 Study Area

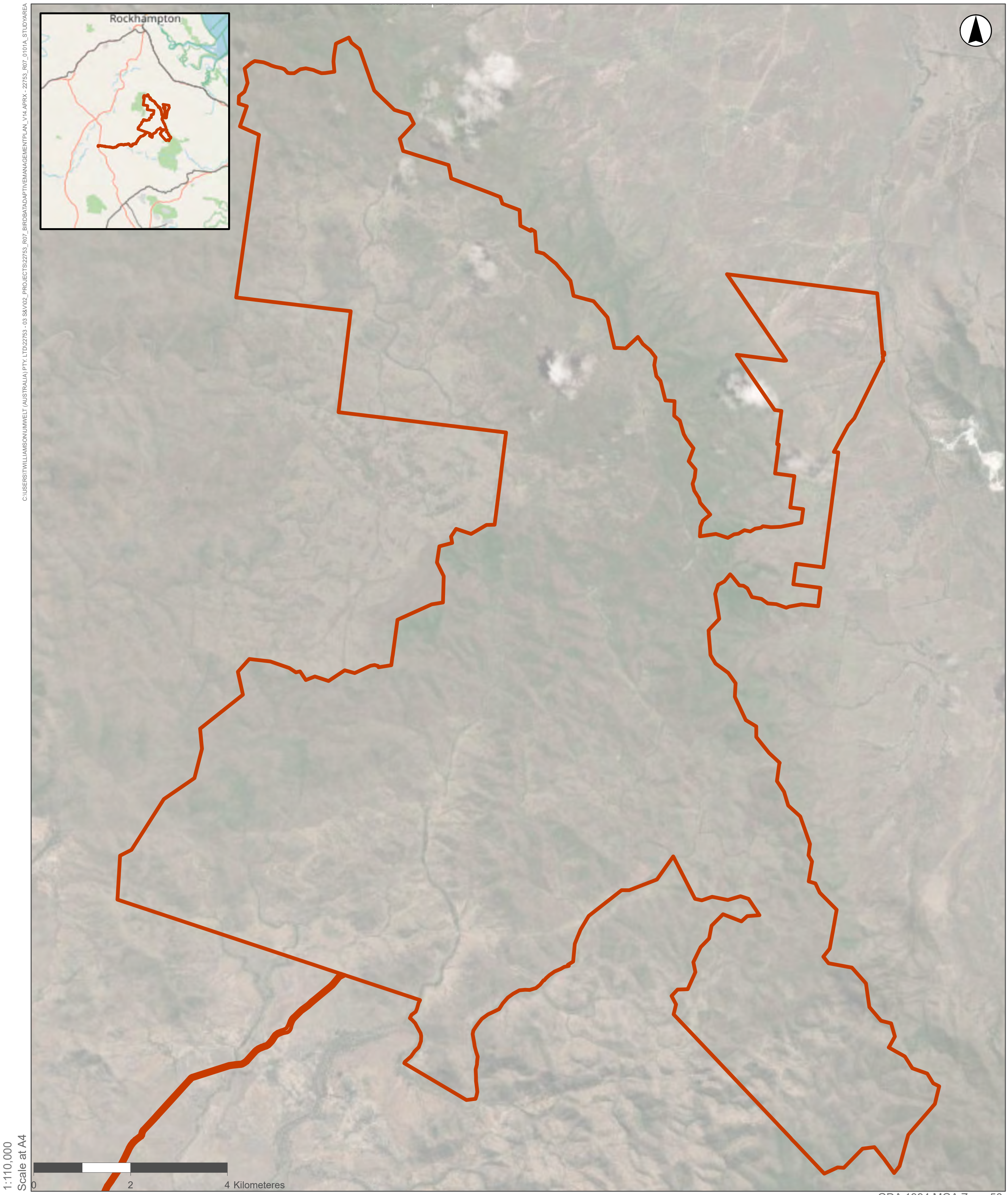
The Study Area refers to the boundaries of the 17 freehold land parcels which encompass the infrastructure that has been designed for the proposed wind farm, as well as the boundary of the access road corridor (inclusive of the local road reserve for Glengowan Road, Playfields Rd and McDonalds Rd and small area of one additional adjacent land parcel) and a connection to the switching station in the road reserve at South Ulam Road. The area covers approximately 16,976 hectares (ha) and extends approximately 25 km north-south at the longest point and 42 km east-west at the widest point (this includes approximately 30 km of access road). The Study Area represents the limit of the vegetation and habitat mapped for the Project. It should be noted however, that this boundary does not represent the spatial bounds in which all Project field surveys have been conducted (this area being larger and including areas outside of the Study Area). Lot and plans relevant to the Study Area include:

- Those relevant to the proposed wind farm:
  - o 148/DS151, 2420/DT4077, 21/RN46, 30/RN72, 50/DT40144, 1933/RAG4058, 21/RN1345, 100/SP289441, 33/DT40123, 2039/RAG4056, 23/RN25, 38/DT40131, 2057/RAG4059, 24/RN34, 25/RN25, 15/RN1089 and 2345/DT4077.
- That relevant to the access road corridor:
  - o 17/RAG4094.

Elevation within the Study Area ranges from approximately 500 m Australian Height Datum (AHD) to 120 m AHD, characterised by hilly terrain that comprises peaks and valleys, with areas of lower, generally flatter topography surrounding the Study Area to the east and west.

Major highways in proximity to the Study Area include the Bruce Highway to the east, Burnett Highway to the west, and the Dawson Highway to the south. These major transport corridors link to the cities of Rockhampton and Gladstone, as well as the Port of Gladstone from which the proposed turbine components will be transported.

The Study Area in the regional context is provided in **Figure 1.1**.



Legend
- Town
- Roads
- Railway
- Watercourses
- Local Government Area (LGA)
- Study Area

FIGURE 1.1A

Study Area Mount Hopeful Wind Farm

Image Source: ESRI Basemap (2022) **Data source:** Department of Resources (2022)

1:100,000
Scale at A4

GDA 1994 MGA Zone 56

Legend
- Town
- Roads
- Railway
- Watercourses
- Local Government Area (LGA)
- Study Area

FIGURE 1.1B

Study Area Mount Hopeful Wind Farm

Image Source: ESRI Basemap (2022) **Data source:** Department of Resources (2022)

2.0 Legislative Context

Relevant Legislation	Governing Agency	Summary	Project Relevance
Commonwealth Legislation			
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	DCCEEW	The EPBC Act is Australia's key piece of environmental legislation. It outlines nine Matters of National Environmental Significance (MNES). Actions that adversely affect MNES may be deemed to be a controlled action under the Act.	The following MNES are relevant to the Project: • Threatened Species. • Migratory Species.
EPBC Act Environmental Offsets Policy	DCCEEW	The EPBC Act Environmental Offsets Policy outlines the use of environmental offsets under the EPBC Act and are considered during the assessment phase of an environmental impact assessment. Specifically, this policy applies to project assessments and approvals under Parts 8 and 9 of the EPBC Act, in addition to strategic assessments under Part 10.	Pending the outcomes of the EPBC Act referral decision, offsets may be required.
State Legislation			
Planning Act 2016 (Planning Act)	Department of State Development, Infrastructure, Local Government and Planning (DSDILGP)	Applications for a Material Change of Use (MCU) for a new or expanding wind farm and Operational Works for Native Vegetation Clearing must be assessed against the benchmarks included in State Code 23 and State Code 16 of the State Development Assessment Provisions 16. Development that is a MCU for a wind farm should demonstrate compliance with 13 performance outcomes (PO) and associated acceptable outcomes within the code.	State Code 23 requires assessment against PO5 – Flora and Fauna: Development is designed, sited and operated to ensure that flora, fauna and associated ecological processes are protected from adverse impacts. State Code 16 requires assessment against benchmarks relating to offset areas, minimisation of clearing, and clearing associated with wetlands, watercourses and drainage features, connectivity areas, Endangered and Of Concern REs, and Essential Habitat.
Nature Conservation Act 1992 (NC Act)	Department of Environment and Science (DES)	The purpose of the NC Act is to conserve biodiversity by creating and managing protected areas, managing and protecting native wildlife, and managing the spread of non-native wildlife.	Where a proposed development will result in impacts to fauna protected under the NC Act, authorisation from the Director General of the DES is required.
Environmental Offsets Act 2014 (EO Act)	DES	An environmental offset condition may be imposed under certain Queensland legislation that applies to development assessment where the activity is a prescribed activity under the EO Act. Activities which have an impact on a Matter of State Environmental Significance (MSES) may require offsetting under the Act.	Consideration of offsetting requirements for the Project will need to be determined once a fixed design for the Project is completed. Requirements for offsets are therefore not discussed as part of this report.

3.0 Baseline Surveys

3.1 Desktop Assessment

An initial desktop assessment was undertaken for the Project to review the potential occurrence of Commonwealth listed threatened and Migratory bird and bat species. The desktop assessment identified 30 threatened and/or Migratory bird species and 4 threatened bat species that have the potential to occur within the Study Area. The desktop review undertaken to support this assessment is provided in the Mount Hopeful Wind Farm Bird and Bat Utilisation Assessment (BBUA) report (**Appendix A**).

3.2 Baseline Survey Methodology

Baseline bird and bat utilisation surveys (BBUS) were conducted within the Study Area between 2019 and 2022. A total of six BBUS (including one site selection and baseline avifaunal data collection survey) were undertaken throughout the survey program, five of which coinciding with the seasonal migration of EPBC Act listed birds, including white-throated needletail (*Hirundapus caudacutus*). The BBUS program totalled 31 days of on-site surveying with two ecologists.

A full report detailing the methods and results of the BBUS is provided in **Appendix A**.

Birds were surveyed from 16 vantage points at elevated positions in the landscape using a timed survey method. Each vantage point was surveyed for one hour during three sampling windows per day to minimise sampling bias. The following information was recorded for each observation made during the survey:

- Species and abundance.
- Observation type (visual or aural).
- Distance and direction from the observer (to the nearest 10 m and 10° respectively).
- Approximate height AGL of the observed bird/s (to the nearest 10 m).
- Direction of flight (to the nearest 10°).
- Flight pattern (i.e., not flying, local movement, directional flight, circling, swooping, varied, other).
- Behaviour (i.e., flight, foraging, perching, mating, aggressive interactions, hollow inspection, nesting, on station).

Incidental observations of birds occupying the Study Area were also recorded, noting the above information where available.

Bat call detectors (Anabat Swift units) were placed at each vantage point for a period of two to five nights during each BBUS. One detector was placed at approximately 50 m AGL for three nights. Across all surveys, the total number of detector nights was 104. Data collected from the detectors was sent to Balance! Environmental for identification.

The location of vantage points and Anabat Swift deployments within the Study Area are provided in **Figure 5.1.**

3.3 Baseline Findings

3.3.1 Bird Utilisation

The bird utilisation survey identified the presence of 5 listed threatened or migratory bird species listed under the EPBC. An additional 5 listed species were identified as having a Moderate or High likelihood of occurrence within the Study Area. These results are presented in **Table 3.1**.

Table 3.1 Known and Potentially Occurring Listed Species

Common Name	Scientific Name	NC Act Status	EPBC Act Status
Known			
glossy black-cockatoo	*Calyptorhynchus lathami erebus*	Vulnerable	-
rufous fantail	*Rhipidura rufifrons*	Special Least Concern	Migratory
spectacled monarch	*Monarcha trivirgatus*	Special Least Concern	Migratory
squatter pigeon (southern)	*Geophaps scripta scripta*	Vulnerable	Vulnerable
white-throated needletail	*Hirundapus caudacutus*	Vulnerable	Vulnerable; Migratory
High			
black-faced monarch	*Monarcha melanopsis*	Special Least Concern	Migratory
oriental cuckoo	*Cuculus optatus*	Special Least Concern	Migratory
fork-tailed swift	*Apus pacificus*	Special Least Concern	Migratory
satin flycatcher	*Myiagra cyanoleuca*	Special Least Concern	Migratory
Moderate			
Latham's snipe	*Gallinago hardwickii*	Special Least Concern	Migratory

Maximum flight heights from two threatened species identified during the BBUS occur within the RSA used in the bird and bat utilisation assessment (between 55 m and 260 m) including white-throated needletail (*Hirundapus caudacutus*) and glossy black-cockatoo (*Calyptorhynchus lathami erebus*).

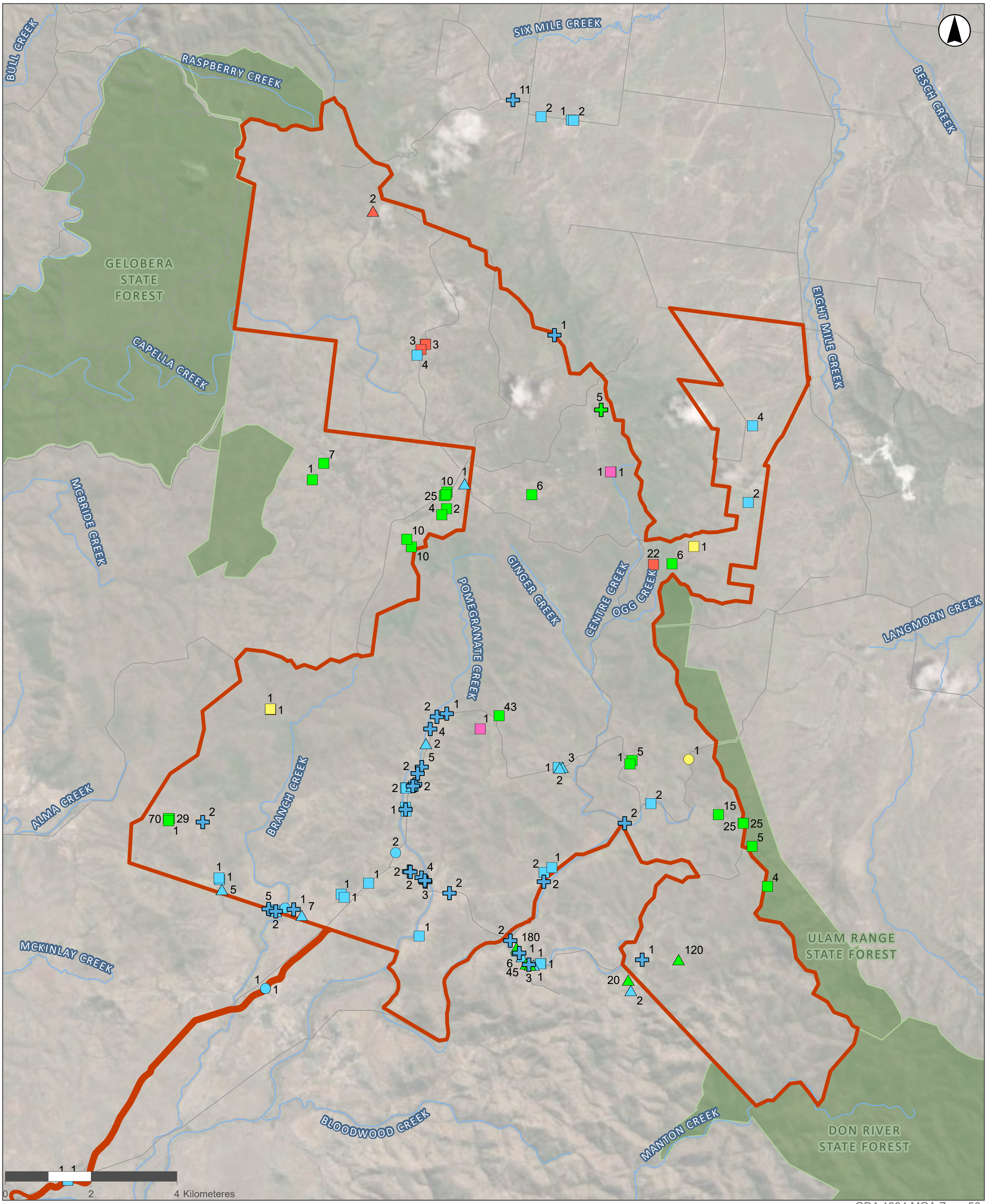
3.3.2 Bat Utilisation

Bat call data identified the presence of 18 microbat species, 9 of which were recorded during every season surveyed. No listed threatened or migratory microbats were recorded during the BBUS.

The likelihood of occurrence assessment identified the grey-headed flying-fox (*Pteropus poliocephalus*) as having a Low likelihood to occur within the Study Area. Grey-headed flying-fox was not recorded during Project associated surveys however several camps (the closest being 10 km northwest of the access road corridor and 28 km from the wind farm component of the Study Area) have been irregularly occupied by a low number of individuals. The distance from the wind farm component of the Study Area is towards the maximum extent of the species known nightly foraging commute and expansive areas of foraging habitat are available between roosts and the Study Area. No Nationally Important Flying-fox Camps are present within the region.

A full list of bat species recorded within the Study Area is provided the BBUA in **Appendix A**.

The locations of threatened and migratory bird and bat species identified during the bird and bat utilisation surveys are provided in **Figure 3.1.**



GDA 1994 MGA Zone 56

Legend

Watercourse
Roads
Study Area
State Forest

Threatened Bird Species

2019

Squatter pigeon (southern) (*Geophaps scripta scripta*)
Rufous fantail (*Rhipidura rufifrons*)

2020

Glossy black-cockatoo (*Calyptorhynchus lathami erebus*)
Squatter pigeon (southern) (*Geophaps scripta scripta*)
White-throated needletail (*Hirundapus caudacutus*)
Spectacled monarch (*Symposiachrus trivirgatus*)
Rufous fantail (*Rhipidura rufifrons*)

2021

Glossy black-cockatoo (*Calyptorhynchus lathami erebus*)
Squatter pigeon (southern) (*Geophaps scripta scripta*)
White-throated needletail (*Hirundapus caudacutus*)

2022

Squatter pigeon (southern) (*Geophaps scripta scripta*)
White-throated needletail (*Hirundapus caudacutus*)

FIGURE 3.1A

Threatened and Migratory Species Locations

Image Source: ESRI Basemap (2022) **Data source:** Department of Resources (2022)

Legend

- Watercourse
- Roads
- Study Area
- State Forest

Threatened Bird Species

2019

- Squatter pigeon (southern) (*Geophaps scripta scripta*)

2020

- Squatter pigeon (southern) (*Geophaps scripta scripta*)
- White-throated needletail (*Hirundapus caudacutus*)

2021

- Squatter pigeon (southern) (*Geophaps scripta scripta*)

2022

- Squatter pigeon (southern) (*Geophaps scripta scripta*)

FIGURE 3.1B

Threatened and Migratory Species Locations

Image Source: ESRI Basemap (2022) **Data source:** Department of Resources (2022)

4.0 Bird and Bat Risk Assessment

A collision risk assessment was undertaken as part of the Project's Bird and Bat Utilisation Assessment (**Appendix A**). The risk assessment considered the likelihood of species presence and conservation status of species observed or indicated to be present in the Study Area, as well as risk to observed species based on flight characteristics. Bird and bat species were considered in the risk assessment if they met the following criteria:

- Bird and bat species listed as threatened and/or migratory under the EPBC Act or NC Act, recorded in the Study Area or deemed to have a Moderate or High likelihood of occurrence in the Study Area.
- Bird and bats species identified as a low likelihood of occurrence, however requested by DCCEEW for further consideration as part of the preliminary documentation.
- Bird species recorded flying at RSA height in the Study Area.
- Bat species recorded in the Study Area that have Moderate to High potential to occur at RSA height.

The risk assessment calculated the likelihood and consequence of risks to each species based on a set of criteria as documented in the BBUA, provided in **Appendix A**.

Data collected during the bird and bat monitoring program (**Section 5.0**) will continue to be incorporated into the bird and bat risk assessment. The likelihood ratings for each bird and bat species assessed in **Appendix A** relates to the species status or frequency of occurrence within the Study Area, and the species known or likely frequency of flights within RSA height. As additional field and desktop data becomes available throughout operation of the Project, the outcome of this criteria for each species may change, thereby potentially affecting the species overall risk rating. Based on pre-commissioning bird and bat data, one species, white-throated needletail (*Hirundapus caudacutus*) has been assessed as having a Very High overall risk rating and as such, was subject to quantitative collision risk modelling (**Section 4.2.1**) to estimate the number of potential collision based mortalities per year.

4.1 Summary of Findings

The risk assessment identified 1 EPBC listed bird species, white-throated needletail (*Hirundapus caudacutus*), as having a Very High overall risk rating reflecting the high likelihood of collision in the Study Area and the potentially high consequence of such given a substantial proportion of the species declining population may occur in and move through the Study Area during the species non-breeding migration.

A further 3 species were assessed based on specific recommendations made in the RFI including:

- Red goshawk (*Erythrotriorchis radiatus*) – Moderate overall risk rating (based on Low likelihood and High consequence).
- Grey-headed flying-fox (*Pteropus poliocephalus*) – Moderate overall risk rating (based on Moderate likelihood and Moderate consequence).
- Ghost bat (*Macroderma gigas*) – Moderate overall risk rating (based on Low likelihood and Moderate consequence).

Assessed as a group, non-listed microbats received a Moderate – High overall risk rating. Of the species detected in the Study Area it is considered probable that 7 species may fly above 55 AGL (the lower limit of the RSA), namely Gould's wattled bat (*Chalinolobus gouldii*), large bent-winged bat (*Miniopterus orianae oceanensis*), northern freetail bat (*Chaerephon jobensis*), eastern free-tailed bat (*Ozimops lumsdenae*), yellow-bellied sheathtail bat (*Saccolaimus flaviventris*) and Troughton's sheathtail bat (*Taphozous troughtoni*).

Further details of the bird and bat risk assessment are provided in **Appendix A**.

4.2 White-throated Needletail

4.2.1 Collision Risk Modelling

A Turbine Collision Risk Assessment was undertaken for white-throated needletail (*Hirundapus caudacutus*) by Biosis Pty Ltd (Biosis). The full assessment is provided in **Appendix B**. The following key inputs were used in the model:

- Bird utilisation data collected during the BBUS including the frequency of observation, individual count per observation and flight height (noting whether the individuals were recorded above or below the rotor height).
- Site-population (estimated at 1,000 individuals).
- Wind farm parameters (63 turbines).
- Turbine specifications based on two potential options (**Table 4.1**).
- The flight speed of the species (estimated at 100 km per hour).
- A bill-tip to tail-tip length of the species (averaged at 21 centimetres).
- The avoidance rate of the species (modelled at three intervals, 0.99, 0.995 and 0.999).

Collision risk modelling for this species was undertaken using two proposed turbine options including the Turbine A and Turbine B. The respective specifications of these turbines are provided in **Table 4.1**.

Table 4.1 Key Turbine Specifications for Two Options

Specification	Turbine A	Turbine B
Rotor hub height	166 m	148 m
Rotor diameter	162 m	164 m
Minimum blade-tip height	85 m	66 m
Maximum blade-tip height	247 m	230 m
Rotational speed	12.1 rpm	9.7 rpm

The results of the model in reference to the respective avoidance rate are provided in **Table 4.2**.

Table 4.2 Annual Collision Risk Model Results for White-throated Needletail

Turbine Option	Estimated Annual Number of Collisions		
	0.99	0.995	0.999
Turbine A	0.172	0.089	0.022
Turbine B	0.166	0.083	0.017

The assessment concludes that at the most conservative avoidance rate of 0.99, the estimated number of collisions per annum associated to the operation of the Project is approximately 0.17 individuals, equating to approximately one white-throated needletail collision every 5.9 years.

5.0 Bird and Bat Monitoring Program

Six pre-commissioning bird and bat utilisation surveys were undertaken within the Study Area between 2019 and 2022. These surveys were undertaken in accordance with the methodology detailed in **Appendix A** and summarised in **Section 3.0**. Based on the survey effort undertaken to support the bird and bat utilisation assessment, no further pre-commission surveys are proposed before construction.

The Project commits to preparing a final BBAMP for approval in consultation with DCCEEW following detailed design of the Project and prior to the operation of the wind farm. The methodology for post-commissioning phase surveys is provided below and based on current information and industry guidelines. However, given the preliminary and adaptive nature of this BBAMP, methodologies or approaches to survey may require adjustment, with any divergences from the below provided in the final BBAMP.

Bird and bat monitoring conducted during the post-commissioning phase will incorporate field survey results collected via both the BBUS and carcass detection program. These are discussed in further detail below.

A desktop assessment of relevant database searches and literature will be completed prior to each survey to inform the survey approach based on the current status of threatened and Migratory bird and bat species in the Project region.

5.1 Survey Schedule

An overview of the survey schedule for the different components of the bird and bat monitoring program is provided below in **Table 5.1**. Timing of the bird monitoring program has been provided based on the southern (October/November) and northern (February/March) migration of EPBC Act listed swifts including white-throated needletail (*Hirundapus caudacutus*) and fork-tailed swift (*Apus pacificus*). Timing of the bat monitoring program has been provided to coincide with the bird monitoring program, as well the flowering of eucalypts in spring and the period post breeding for flying foxes. This timing also coincides with the optimal seasonality for surveying for microbats based on an increase in prey abundance.

Table 5.1 Survey Schedule

Survey	Timing	Duration
Bird Utilisation Survey	Twice annually, in October/November and February/March following commencement of operation.	2 years
Bat Utilisation Survey	Twice annually, in October/November and February/March following commencement of operation.	2 years
Carcass search surveys	Seven carcass searches will be conducted once per month from October–April during warmer months. A further two carcass searches will be conducted during alternating months from May–September. Timing of carcass search surveys has been provided in **Table 5.2.**	2 years
Carcass persistence trial	Once every 6 months following commencement of operation.	2 years
Carcass detectability trial	Once every 6 months following commencement of operation.	1 years

5.1.1 Bird and Bat Utilisation Surveys Bird Utilisation Surveys

Bird utilisation surveys are to be conducted within 3 months of commencement of wind farm operation and will continue during the first two years of operation. To ensure the site is safe and accessible, surveys will not be permitted to commence until the following conditions are satisfied:

- All turbines are commissioned and tested (including testing dependent on wind conditions).
- All turbines have been handed over from the Supply and Installation Contractor to the Developer.
- Australian Energy Market Operator testing is complete (grid compliance testing).

Prior to this occurring, the Project will be considered to be in the construction phase with the site containing exclusion zones due to construction and/or testing work.

Post-commissioning bird utilisation surveys will be conducted using a variety of survey techniques including but not limited to those undertaken in the pre-commissioning surveys. These methods are discussed in detail below.

The survey approach and method should align with that of the bird surveys conducted in between 2019 and 2022 to allow robust comparison of results. For the purpose of reporting, any observation of a bird or birds flying at RSA height constitutes ‘at risk behaviour’. An outline of the survey approach is provided below.

5.1.1.1 Vantage Point Surveys

Post-commissioning vantage point surveys will be conducted as per the methodology described in **Appendix A**, including the undertaking of point based visual and aural counts of bird species using the Study Area.

During each vantage point survey, a single observer will record the following information for each observation:

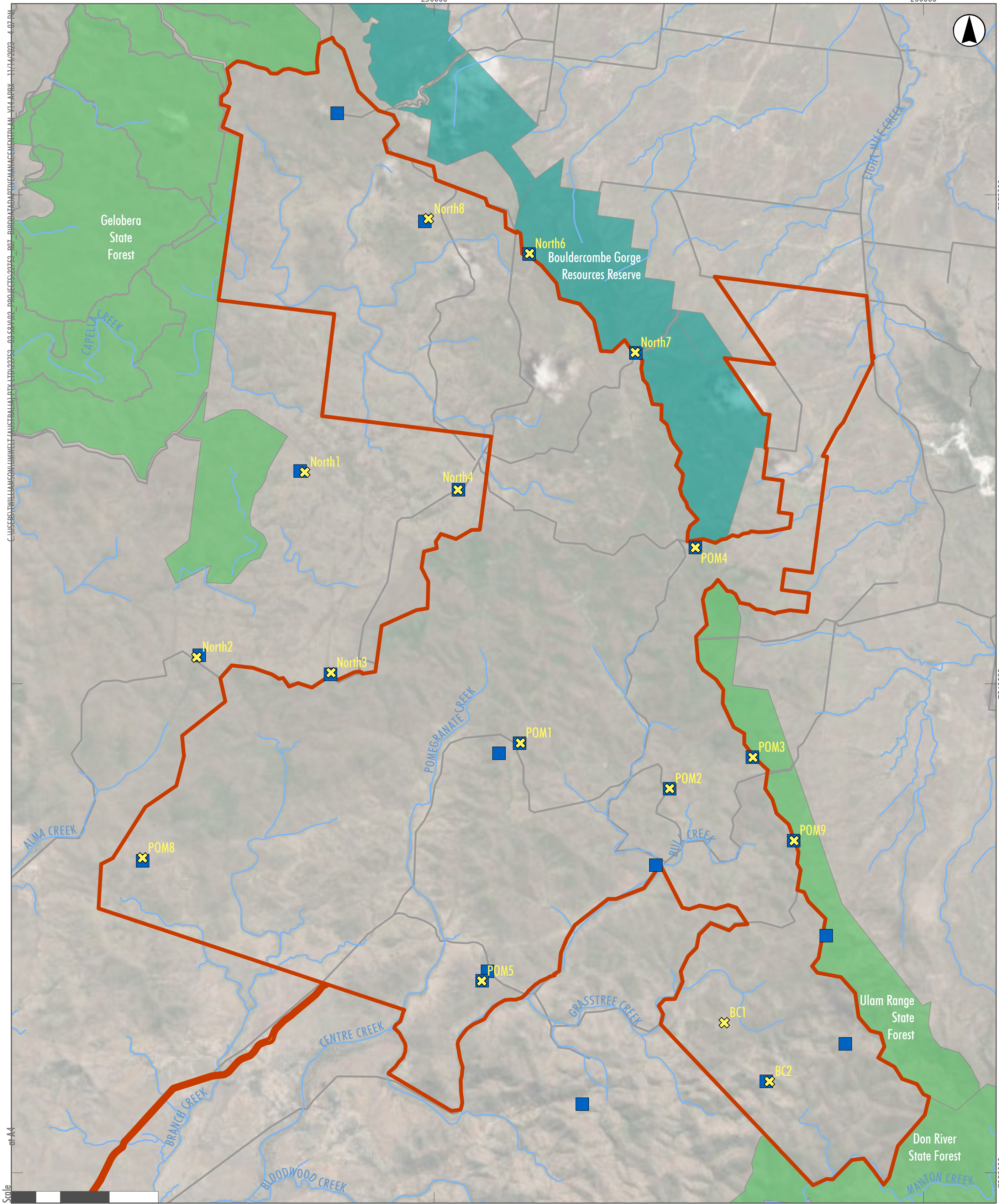
- Species and abundance.
- Observation type (visual or aural).
- Distance and direction from the observer (to the nearest 10 m and 10° respectively).
- Approximate height AGL of the observed bird/s (to the nearest 10 m).
- Direction of flight (to the nearest 10°).
- Flight pattern (i.e. not flying, local movement, directional flight, circling, swooping, varied, other).
- behaviour (i.e. flight, foraging, perching, mating, aggressive interactions, hollow inspection, nesting, on station).

Vantage Point Sampling locations:

Due to access constraints during the pre-commissioning survey, not all turbine locations / areas could be accessed safely, and the 1-hour survey duration was found to optimise results with travel time between locations. It is assumed that post-commissioning survey events will have unrestricted access to each turbine location, and therefore, a review of survey duration and total number of vantage points will be determined following final design.

At a minimum, vantage point surveys should be conducted at the following existing vantage point locations: North 6, North 7, POM 4, POM 3, POM 1, BC1 and BC2 (**Figure 5.1**).

Reference sites should be established, ideally at existing vantage point locations: POM8 and North4 (**Figure 5.1**). The final location of reference sites is subject to land access agreements.



Legend
- Vantage Survey
- Anabat Location
- Watercourse
- Roads
- Study Area
- Resources Reserve
- State Forest

FIGURE 5.1

Vantage Point Survey Locations

5.1.1.2 Diurnal Bird Area Searches

Diurnal bird areas searches comprise a standard two ha 20-minute search of habitat and recording all observed or heard bird species. The objective of the area searches is to collect data on relative abundance and to a lesser degree, flight behaviour, of bird species across different vegetation types within the Study Area.

Area searches are proposed to be conducted at 50% of turbines per survey event (2 events per year). Survey locations should be positioned within habitat immediately adjacent to turbines. Over the course of each year, habitat in proximity to every turbine should be sampled.

5.1.1.3 Bird Utilisation Surveys Timing

Post-commissioning bird utilisation surveys will be conducted for the first two years of operation and are to be conducted twice annually to coincide with the seasonal migration of EPBC Act listed birds, including white-throated needletail (*Hirundapus caudacutus*). Surveys should be conducted between October and April, with preferred timing being late October to November and February to mid-March.

The requirement for ongoing post-commissioning bird utilisation surveys will be reviewed after the initial two years of surveying.

5.1.2 Bat Utilisation Surveys

Post-commissioning bat utilisation surveys will be conducted using a variety of survey techniques including but not limited to those undertaken in the pre-commissioning surveys. These methods are discussed further below.

5.1.2.1 Flying-fox Survey

Utilisation of the Study Area by flying-foxes will continue to be assessed during commissioning by undertaking fly-out surveys from pre-determined vantage points. Site selection will be determined prior to post-commissioning surveys being undertaken. Each survey will involve a timed search during the hours of dusk (depending on sunrise and sunset times) to determine the following:

- Species and abundance.
- Distance and direction from the observer (to the nearest 10 m and 10° respectively).
- Approximate height AGL of the observed flying-fox (to the nearest 10 m).
- Direction of flight (to the nearest 10°).

Desktop monitoring of regional flying-fox camps will also be undertaken to determine the possibility of threatened flying-foxes moving into the Study Area.

5.1.2.2 Bat Call Detector Surveys

Bat call detectors will be placed at previously selected vantage points and turbines at approximately two metres AGL and left for between two to five nights. Site selection will be determined prior to post-commissioning surveys being undertaken.

Where possible, bat call detectors will be placed at hub height on turbines by an appropriately qualified person with guidance provided by an ecologist.

5.1.2.3 Bat Utilisation Survey Timing

Post-commissioning bat utilisation surveys will be conducted for the first 2 years of operation and are to be conducted twice annually, in conjunction with bird utilisation surveys. The requirement for further post-commissioning bat utilisation surveys will be reviewed after the initial 2 years of surveying.

5.2 Carcass Search Program

The key objective of the carcass detection program is to estimate the frequency of bird and bat mortality due to collision associated with the Project from which the total number of collisions can be determined. The methods to be employed as part of this program are detailed below. Reporting requirements relevant to the mortality assessment program are described in **Section 8.0**.

5.2.1 Turbine Search Selection

All turbines within the Project are regarded as high-risk for the white-throated needletail (*Hirundapus caudacutus*) (refer **Section 5.2.1.1** for further detail). On this basis, all turbines will be surveyed for carcasses equally over the course of the two-year program.

It is proposed that a maximum 50% of turbines will be searched during any one event, alternating between survey events. Additional surveys beyond the proposed maximum may be considered during each survey event, with consideration of following factors:

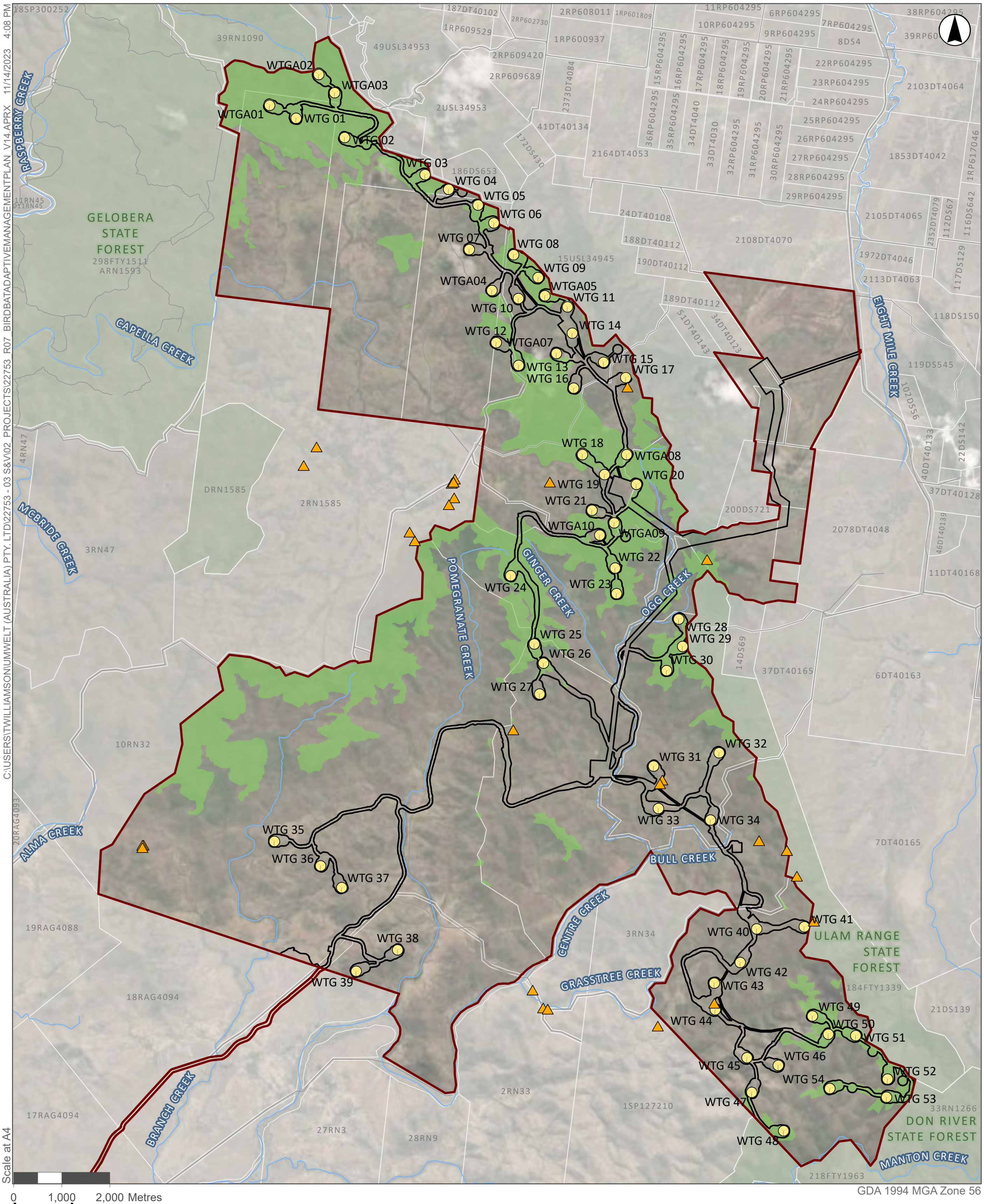
- Turbines where prior mortality events of threatened or migratory species have been confirmed.
- Turbines that overlap or occur in proximity with habitat for threatened or migratory birds and bats.
- Turbines representative of different habitat types and landscape positions.
- Spatial coverage across the Project.

The randomisation of turbine search order would be beneficial over the course of the detection program.

5.2.1.1 High-risk Turbines for White-Throated Needletail

The bird and bat risk assessment identified that the white-throated needletail (*Hirundapus caudacutus*) has a Very High overall risk of operational Project impacts (**Appendix A**). The species is known to occur in high abundances during the non-breeding migration period and display a high degree of mobility, therefore, all turbines are classified as high-risk turbines to the species.

The location of the turbines within the Study Area in relation to the white-throated needletail (*Hirundapus caudacutus*) records and potential habitat is provided in **Figure 5.2**.



Legend

- High Risk Turbines (All)
- White-throated Needletail Records
- White-throated Needletail Roosting and Foraging Habitat
- Property Boundaries
- Study Area
- Development Corridor

FIGURE 5.2

HIGH RISK TURBINES AND WHITE-THROATED NEEDLETAIL

Image Source: ESRI Basemap (2022) **Data source:** Department of Resources (2022)

NB: Layout is Indicative Only

5.2.2 Survey Timing and Frequency

The carcass detection program will run for an initial 2 years starting within three months of commencement of operation of the wind farm. The timing and frequency of the carcass detection surveys is shown in **Table 5.2** and described below:

- Seven carcass searches will be conducted once per month from October to April during warmer months when several threatened or migratory species may be present or more active.
- Two carcass searches will be conducted during alternating months from May–September.

Table 5.2 Carcass search survey timing and frequency,

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Survey Timing					No survey		No survey		No survey			

The search program will be reviewed for efficacy after 2 years, with the possibility of extension for a further three years (potential total of 5 years). The efficacy requirement for extension will be based on a circumstance where there is clear discrepancy between estimated and realised frequency of bird and bat morality due to collision from the operation of the wind turbines associated with the Project.

5.2.3 Search Area

The final search area engaged for the carcass detection program will be determined based on the confirmation of final specifications of the proposed turbines. Based on proposed RSA used in the risk assessment as well as the findings of Hull and Muir (2010), Huso and Dalthorp (2014) and Prakash and Markfort (2020), an indicative area with a radius of 120 m comprising an inner and outer search area (60 m and 120 m radii respectively) will be surveyed at each of the selected sites.

Carcass searches will be conducted as follows:

- The inner and outer search areas will be surveyed at each selected turbine. Turbines will be selected based on an alternating schedule, with all turbines sampled after the completion of two survey events.
- If the monthly survey event in September to April identifies any carcass or feather spot of an MNES, a follow up survey of the inner search area will be undertaken to bolster detection rates.
  Best endeavours will be used to complete this survey within four days after the first survey event.

The frequency of carcass search surveys may be altered, in consultation with DCCEEW, if the findings of the carcass persistence trial indicate that it would be necessary or appropriate.

5.2.3.1 Unsearchable Areas

Eucalypt woodland, vine forest and steep and potentially dangerous terrain may remain within the carcass search area following vegetation clearance of the hardstand, roads and other infrastructure. At such turbines, searcher efficacy or carcass detectability (particularly if humans are used to search for carcasses rather than dogs) may vary.

To account for this, areas deemed unsearchable for each turbine included in the carcass search program must be mapped and a corrective function to estimate total carcass numbers applied.

5.2.4 Search Method

Two potential search methods, being the use of detection dogs and a human detection search method are provided for below.

5.2.4.1 Detection Dog Method

Trained detection dogs will be used if available and the climatic conditions of the Project and the terrain of the search areas are suitable for a safely and effective search. Surveys conducted during summer months may need to be scheduled around hot weather. The terrain of the search areas may present some limitation to the detection dog and trainer, where dense vegetation and steep, rocky terrain occurs.

During each turbine search, a dog and handler would traverse the search area along paths spaced by approximately 20–30 m from one another depending on wind speed (high winds potentially impacting scent detection). The spacing of the paths within this range would be determined by the handler. The dog would be fitted with a GPS unit to provide a measure of coverage completed during each survey.
Dog handlers will be trained and experienced in identification of all bird and bat species that may occur within the Project site.

5.2.4.2 Human Detection Survey Method

If a trained detection dog is unavailable carcass searches will be conducted by ecologists experienced in identification of carcasses of bird and bat species that may occur within the Project site. At each turbine search area, the observer will walk transects spaced by 6 m within the inner search area and 12 m within the outer search area. The observer will record their movement along transects using a handheld GPS device.

5.2.5 Data Collection and Carcass Find Protocol

During the carcass search surveys and the carcass persistence trials (**Section 5.2.7**), data will be collected and recorded on predefined survey sheets, including online applications if appropriate. The data will include general information such as basic survey and weather information and will include other location specific factors such as the estimation and ongoing consideration throughout each individual turbine search, namely, the extent of different ground substrates and the extent of the search area that is accessible/searchable.

In the event that a bird or bat carcass or featherspot is detected during a carcass search survey, the carcass or featherspot must be collected, photographed and stored (if a carcass), its location must be recorded on a GPS device and the relevant data collection form completed. Handling and collection of carcasses should consider the following:

- The carcass must be removed from the site by a person wearing rubber gloves, and double bagged in plastic bags.
- The carcass must be photographed in such a way that it can be further identified, i.e. on a white background with an item or measure for scale and adequate lighting.

- A label with the date, turbine number, species name (if known) and a unique specimen code must be placed in the second bag to allow cross-reference to the corresponding completed datasheet.
- The carcass will be transported to a freezer where it will be retained for the purpose of either a second opinion on its identification, or for use in carcass persistence trials or carcass detectability trials.

In cases where featherspots or carcasses are not able to be identified, the following process will be undertaken:

- Photos of the featherspot or carcass will be analysed by the lead ecologist (including any colleagues) to definitively identify the find, including circumstances where the lead ecologist allocated the identification to likely or probable confidence levels.
- Methods to further definitively identify the featherspot or carcass could then involve sending photos of the find and/or the find itself to a species specialist or museum or send for DNA testing. DNA swabs are not proposed to be used for carcasses or featherspots unless there is a potential it could be a threatened species or would trigger a non-threatened species impact trigger.

All data collected during the carcass search program will be entered into a database. Data pertaining to incidental findings must also be retained in this database. A second database which will serve as an inventory of carcasses collected is to be maintained by the Environmental Representative within which records detailing whether carcasses are retained, disposed of or sent off-site (i.e. to an authority such as or the Australian Museum) will be managed.

5.2.6 Carcass Detectability Trial

The efficacy of carcass detection program will be investigated using carcass detectability trials which aim to detect the degree of error present as a calibration factor.

The detectability of carcasses under turbines can vary depending on a range of factors such as efficacy of the observer, size of the carcass and type of ground cover. Given this, carcass detectability trials will be undertaken to determine the efficacy of the dog and handler or the ecologist undertaking searches at finding carcasses within the Project site.

The broad methodology to be followed is listed below and includes:

- Carcasses of previously deceased birds and bats collected during the carcass detection program will be stored in a suitably designated freezer and used in the carcass detectability trial.
- Five carcasses of varying size and species (both bird and bat) will be placed around a turbine, and their location captured using a GPS.
- The ecologists or detector dog team, without the knowledge of the calibration survey, will undertake the carcass detection program as per the methodology outlined.

This method enables results of the carcass detection program to be corrected using a calibration factor, derived from the number of placed carcasses found, divided by the number of carcasses placed. For example, if three carcasses of the original five are found by the surveying team, the calibration factor of 0.6 (3/5) would apply to the results of the carcass detection program. In this example, it is assumed at 40% of the carcasses were missed and should be accounted for.

Carcass detection trials will be undertaken once every 6 months during the first year following operation of the wind farm. The trial can be undertaken concurrently with the carcass persistence trials and/or the carcass search surveys to maximise survey efficiency.

5.2.7 Carcass Persistence Trial

Birds and bats injured or killed through collision with turbines may be removed from search areas by scavengers such as raptors, ravens, and a suite of introduced mammals. To estimate persistence rates of different sized carcasses beneath turbines within the Study Area (to aid estimation of mortality rates of birds and bats impacted by turbines) a carcass persistence trial will be undertaken.

The types of carcasses used in the persistence trials should vary between large animals such as raptors or waterbirds, and small animals such as parrots and microbats. The various carcasses will be placed within a defined distance of a selection of turbines within the Study Area. Each carcass will have a motion detecting camera placed nearby to identify the species potentially scavenging on the carcass and record the date and time that the carcass is removed. The use of motion detecting cameras may be replaced with another suitably efficient and accurate method if one should become available.

Quantifying the mean and confidence interval of the time to removal of carcasses is required for input into calculation of mortality estimates. Carcass persistence would be examined through survival analysis using statistical software to estimate the survival function.

The methodology and timing proposed for the carcass persistence trials is expected to be reviewed and developed in further detail once the operational phase of the Project has begun.

6.0 Impact Triggers and Adaptive Management Processes

This section defines impact trigger levels for threatened and migratory species, as well as the adaptive management process which is to be engaged (where trigger levels are met or exceed).

The main objective of setting an impact trigger level is to prevent the operation of the wind farm resulting in adverse impacts on threatened bird and bat species.

6.1 Threatened Species Impact Trigger

The impact trigger for a threatened bird or bat species is the confirmation of 1 carcass or injured individual as recorded during the carcass detection program or detected within 200 m of project infrastructure as part of carrion removal procedures or incidentally during other activities.

6.1.1 Response and Reporting Requirements

If identification (including DNA testing) is required to determine the species of a carcass, then the impact trigger will occur from the date the species of the carcass is confirmed as a threatened species.

If an impact trigger level for threatened species is met or exceeded, a further investigation and reporting response is required. It is the responsibility of the person who discovered the carcass, injured individual or featherspot to notify the site Environmental Representative upon discovery, so the response can be initiated. As part of the response plan, Neoen will initially notify DCCEEW of the event within five business days. A report will be compiled by the contracted ecologist and submitted to DCCEEW within 10 business days of the threatened species carcass being identified.

The adaptive management process depicted in **Figure 6.1** will then be followed.

6.1.2 Species Specific Measures

Further detailed in **Section 6.3**, incremental impact trigger thresholds for white-throated needletail are identified. The intent of these thresholds is to prevent or mitigate adverse impacts to a threatened species or nationally important numbers of a population.

Further measures for red goshawk are also provided. Whilst the occurrence of the species is unlikely, the intent of these measures is to ensure the appropriate adaptive management response, should a nest or individual be discovered.

6.2 Migratory Species Impact Trigger

Impact trigger levels for species listed under the EPBC Act as migratory have been developed using the *Referral guideline for 14 birds listed as migratory species under the EPBC Act* (Department of the Environment 2015). The referral guidelines document that an important population of these species is 0.1% of the national population. For this Project, 0.05% of the national population has been used as the trigger level. Migratory bird species which are known to the Project or have a Moderate or High likelihood of occurrence along with their respective impact trigger levels are provided in **Table 6.1**.

Other Migratory bird species assessed as having an Unlikely or Low likelihood of occurrence within the Study Area have not been included in **Table 6.1**. In the event that carcasses of these species are detected, the BBAMP will be revised and a trigger level of 0.05% will apply.

Table 6.1 Impact Trigger Levels for Migratory Species that are Known or May Occur

Common Name	Scientific Name	Trigger Level (0.05% of Population)
rufous fantail	*Rhipidura rufifrons*	2,400
spectacled monarch	*Monarcha trivirgatus*	325
black-faced monarch	*Monarcha melanopsis*	230
oriental cuckoo	*Cuculus optatus*	500
fork-tailed swift	*Apus pacificus*	50
satin flycatcher	*Myiagra cyanoleuca*	850
Latham's snipe	*Gallinago hardwickii*	950*

** Initial population estimate sourced from the Action Plan for Australian Birds (Garnett & Baker 2020).*

6.2.1 Response and Reporting Requirements

Identification (including DNA testing) is required to determine the species of a carcass, then the impact trigger will occur from the date the species of the carcass is confirmed as a migratory species.

If an impact trigger level for threatened or migratory species is met or exceeded, a further investigation and reporting response is required. It is the responsibility of the person who discovered the carcass, injured individual or featherspot to notify the site Environmental Representative upon discovery, so the response can be initiated. As part of the response plan, Neoen will initially notify DCCEEW of the event within five business days.

The adaptive management process depicted in **Figure 6.1** will then be followed.

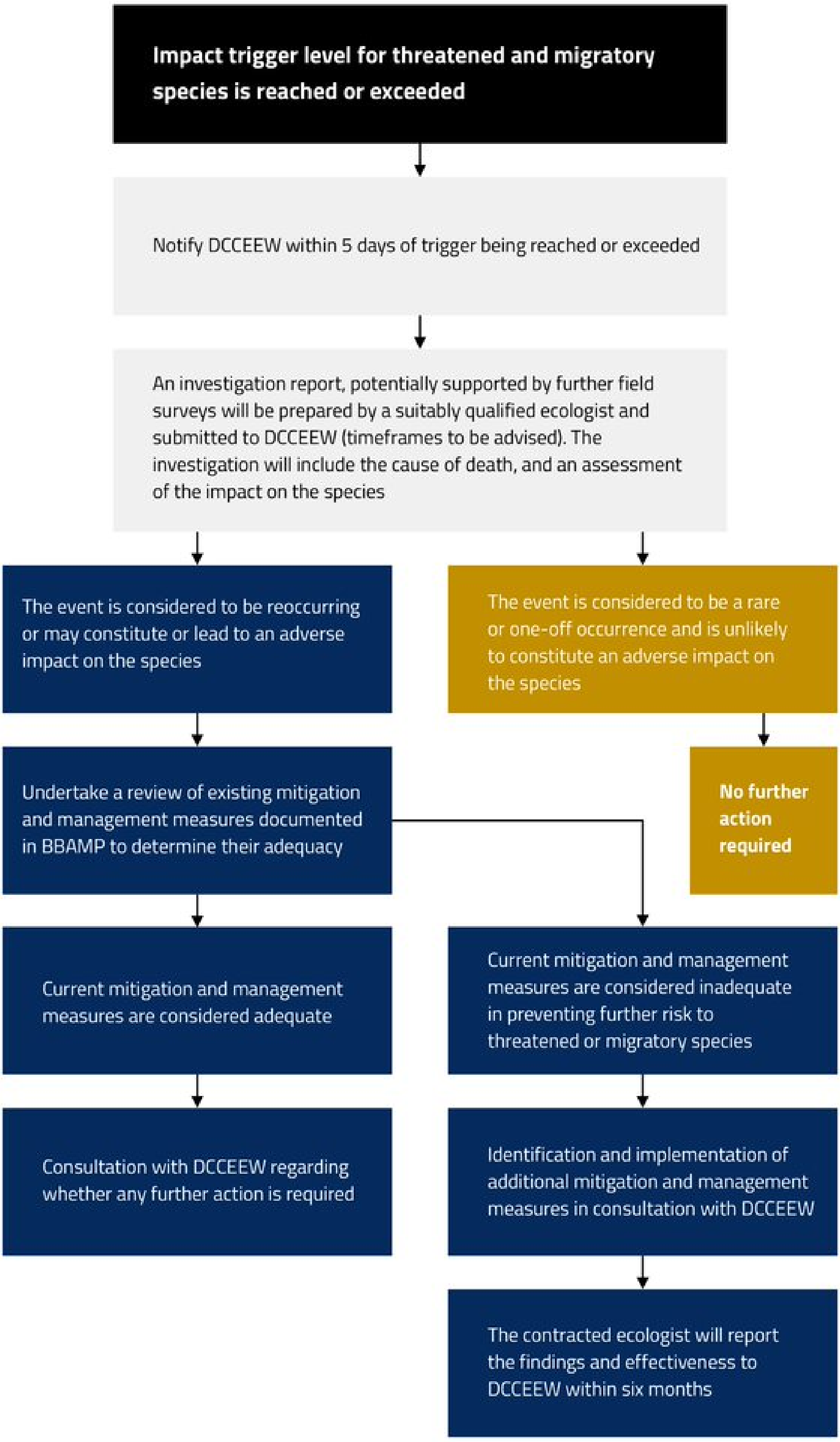


Figure 6.1 Threatened or Migratory Species Impact Adaptive Management Procedure

6.3 Very High Overall Risk Trigger

Data collected during the bird and bat monitoring program will be assessed in accordance with the bird and bat risk assessment methodology outlined in **Appendix A** to improve the understanding of the risk of turbine collision and barotrauma impacts. The bird and bat risk assessment will be updated upon the two year review and, where required, incorporated into the annual monitoring report as specified in **Section 8.0**.

In the event that bird and bat data collected during the monitoring program changes a likelihood rating such of a species such that the overall risk rating is increased to Very High, the following process will be followed:

- Commissioning of a Collision Risk Assessment for the Very High overall risk species to determine the estimated number of collisions per year based on current Project operation.
- Undertake a review of the current mitigation and management measures identified in the BBAMP and determine their adequacy to prevent impact to the species.
- Engage in consultation with DCCEEW to identify further mitigation and management measures to reduce the risk to the species based on turbine collision and barotrauma.

7.0 Mitigation and Management Measures

The purpose of this section is to provide details of mitigation measures to manage risk of the Project leading to a significant impact on birds and bats. Additional measures may be implemented following the investigation of triggers being reached or exceeded and the BBAMP reviewed. The ongoing, preventative mitigation measures discussed in this plan are provided in **Table 7.1**.

Table 7.1 Ongoing, Preventative Mitigation Measures

Mitigation Measure	Description	Timing
Carrion removal program	The presence of carrion around wind turbines attracts many bird species, particularly raptors, placing them at an elevated risk of collision with turbine blades. A carrion removal program will run for the operational lifetime of the Project and will apply to any carcass found within 200 m of turbines in accessible areas, of carcasses other than those of birds and bats. The following procedure will be adopted: • The Environmental Representative or another suitable person will be appointed as the carrion removal coordinator. This person will be responsible for the organisation of monthly inspections by appointed staff. Inspections will be completed by vehicle and/or on foot of accessible areas up to 200 m of turbines. All full-time employed site personnel will be trained on the carrion removal procedure. • All bird or bat carcasses should be stored in a double-wrapped plastic bag and placed in a freezer located on site with the appropriate information labelled for identification. • The following information will be collected for each bird or bat carcass: specimen number, GPS location, species, date and time, visible signs of injury, photographs of the carcass, weather conditions. • The location and date of discovery and date of removal of all non-bird or bat carcasses will be recorded and maintained in a database by the carrion removal coordinator. • Any feral or overabundant native animal control program implemented must include the removal of all carcasses from the Project. • Any carrion detected incidentally outside the carrion removal inspection is to be removed in a timely manner. Following 2 years of operation, the carrion removal program may be adjusted, subject to consultation with DCCEEW. An annual summary of carcass detection and removal will be provided in each Annual Report. Carcasses stored in the on-site freezer will be left until a suitably qualified person (ecologist undertaking carcass detection surveys) is present to complete the identification of the species. Photos collected of the carcass during carrion removal will be used to aid identification. Carcasses will be kept in the on-site freezer for the initial two years of operation of the wind farm for use in the mortality count calibration surveys.	The operational life of the Project, to be reviewed after 2 years from the commencement of the BBAMP

Mitigation Measure	Description	Timing
Lighting and Deterrents	Artificial lights on tall, man-made structures such as communication towers are known to increase collision risk for birds and bats. Steady-burning lights on communication towers increase the risk of collision for nocturnal migrants (Longcore, Rich & Gauthreaux 2008), however communication towers with red strobe, red flashing, and white strobe lights result in less mortality than towers with steady-burning lights (Gehring, Kerlinger & Manville 2009). If lighting of wind turbines is required, strobe/flashing lighting should be considered if it is acceptable to relevant aviation authorities (i.e. Civil Aviation Safety Authority).	Operational life of the Development
White-throated Needletail	In addition to the adaptive management procedure documented in **Section 6.0**, further controls will be placed on the Project should an increase in mortality be identified as below: Impact Threshold Level 1 • Defined as 20 individuals killed between 1 July and 30 June the following year. • An indirect offset will be negotiated with DCCEEW following the exceedance of this threshold level. The details of this offset will be further provided following consultation with DCCEEW, post approval following detailed design. • Introduce curtailment measures, including altering cut-in speeds during diurnal and seasonal operation on turbine/s identified as contributing to the white-throated needletail impact threshold 1. The final scope of curtailment measures is subject to investigation as outlined in **Figure 6.1** and consultation with DCCEEW. Impact Threshold Level 2 • Defined as 41 individuals killed between 1 July and 30 June the following year. • Cease diurnal operation during migratory periods of turbine/s identified as contributing to the white-throated needletail impact threshold 2 (turbines where white-throated needletail carcasses have been identified during carcass detection program) and any additional turbines that later contribute to exceedance. The operation will only recommence once the BBAMP has been updated to include further measures to avoid and mitigate the risk of further impacts to the white-throated needletail. • Notification to DCCEEW of the action to cease diurnal operation of contributing turbines and consultation with DCCEEW to identify additional turbines to be ceased to prevent further blade strike.	During operation

Mitigation Measure	Description	Timing
Red goshawk	Pre-clearance nest surveys will be undertaken for red goshawk within the Disturbance Footprint. Searches will be undertaken during fauna spotter catcher pre-clearance surveys whereby suitably qualified fauna spotter catchers will actively search for red goshawk nests. Where a potential nest is identified, clearance activities within the area will cease and a suitably qualified ecologist will undertake an investigation to determine the species that the nest belongs to. If the nest does not belong to a red goshawk, or any other threatened or migratory fauna species, clearance activities will continue as planned in accordance with the Project management plans. In the event that a red goshawk nest is identified within the Study Area DCCEEW will be notified within 10 business days. A review of the current mitigation measures outlined in the BBAMP, and recommendation of additional actions will be made where necessary.	During construction

Relevant mitigation measures to be considered should a threatened impact trigger be reached, and the investigation has deemed the event to be a regular occurrence or constitute an adverse impact on the species may include measures in **Table 7.2**.

Table 7.2 Potential Mitigation Measures

Potential Measure	Suitability / Application
Altering turbine cut-in speeds	Potential response for reducing microbat mortality events. Increasing the cut-in speed of wind turbines (the velocity at which turbines start producing electricity) may reduce microbat mortality partly because bat mortality rates are generally higher during nights with low wind speeds.
Painting turbine blades	Increases rotor visibility for birds. Suitability of application for all species is unknown and would require further validation. May contradict other aspects of Project approval (visual impacts).
Temporary shutdown of turbines	Employing temporary shutdown of turbines may be an effective measure for reducing fatalities of certain birds and bats. Shutdowns measures could target periods when species presence / activity is highest.
Acoustic deterrents	Ultrasonic deterrent has been implemented and studied internationally. Results have been shown to reduce microbat mortality events, albeit with varying success rates across species. Further investigation would be required for suitability in the eastern Australia context. May contradict other aspects of Project approval (noise impacts).
Offsetting impacts	Includes direct offsets such as the management or improvement of habitat, or indirect offsets funding a conservation measure or other offsets as may be agreed by DES and DCCEEW.

These mitigation measures and associated timing are to be determined if the threatened and non-threatened impact trigger response procedure determines that an impact trigger will potentially be a regular occurrence or may constitute or lead to an adverse or significant impact on the local, regional, or total population of a species. Baseline information gathered during Project operation will inform the success of mitigation measures. The additional mitigation measures, if determined to be necessary must be complaint with the requirements of the EPBC Approval.

Mitigation measures will be investigated when an impact trigger has been met to ensure the appropriate species-specific mitigation action is taken.

8.0 Reporting Requirements

The proposed reporting requirements of this BBAMP are identified in **Table 8.1** below.

Table 8.1 Reporting Requirements

Report	Description	Timing
Carcass Search Program	Following each year of the carcass search program, the program findings will be compiled and submitted to the DCCEEW within 2 months of survey completion. The report should detail the species impacted including: • Total carcasses/featherspots detected of each species. • Locations of carcasses/featherspots detected. • Dates carcasses/featherspots were detected. • Details of any carcass/featherspots detections that triggered impact levels. The number of carcasses of each species identified during the carcass search program which are utilised in the detectability trials will also be reported. Statistical analysis should be undertaken to provide estimates of the annual total number of collisions for each species in consideration of the carcass search area and effort and the observed carcass persistence times and observer detectability rates. A second report detailing the findings of the entire carcass search program must be submitted to DCCEEW within two months of completion of 24 months of surveys.	Annually for 2 years, within 2 months of survey completion.
Impact Trigger Reporting	DCCEEW and DES must be notified within five days from when the impact triggers are met. The report compiled by the contracted ecologist must then be submitted to the DCCEEW within 10 business days. The impact trigger report will include: • The impact trigger level that was reached. • The species and number of individuals involved in the impact trigger. • The date/s and location/s of recovered carcasses/featherspot. • Any identified ecological factors contributing to the impact trigger such as climate, presence of prey species/foraging opportunities, seasonal factors (i.e. migration). • Whether the event is likely to be rare or regular or may constitute an adverse impact on the species at the local, regional or total population scale. In cases where further monitoring or implementation of mitigation measures is deemed necessary through consultation with DCCEEW, the findings and effectiveness of such must be reported to DCCEEW within three months of the commencement of monitoring or the implementation of mitigation measures or within another specified timeframe as determined through consultation with DCCEEW.	If an impact trigger occurs in accordance with **Section 6.0**.

Report	Description	Timing
Annual Report	Annual compliance reporting will include a summary of any bird and bat monitoring program implemented throughout the year. It is anticipated that relevant information may comprise: • Provision of information regarding all turbine strikes, including method of detection, factors regarding the presence of a species, prevailing conditions at the time of collision. • Estimations of annual mortality and injury for each relevant threatened and migratory species. • Listed species occurrence records. • Evaluation regarding the effectiveness of measures implement to avoid and mitigate mortality and or injury to threatened and migratory species.	Annually
	Following the completion of 24 months monitoring, the annual report will include discussion of the following items based on ongoing bird and bat monitoring data: • The development and implementation of tangible, on-ground management measures and corrective actions to promote a long-term reduction in the risk of turbine collision and barotrauma impacts on listed bird and bat species. • The identification of any changes to site utilisation by listed bird and bat species. • An updated bird and bat risk assessment to continually develop the understanding of risk to birds and bats species from Project operation. • An improved understanding of whether or how Project site usage changes as a result of wind farm construction and operation.	Upon completion of 24 months of monitoring.

9.0 References

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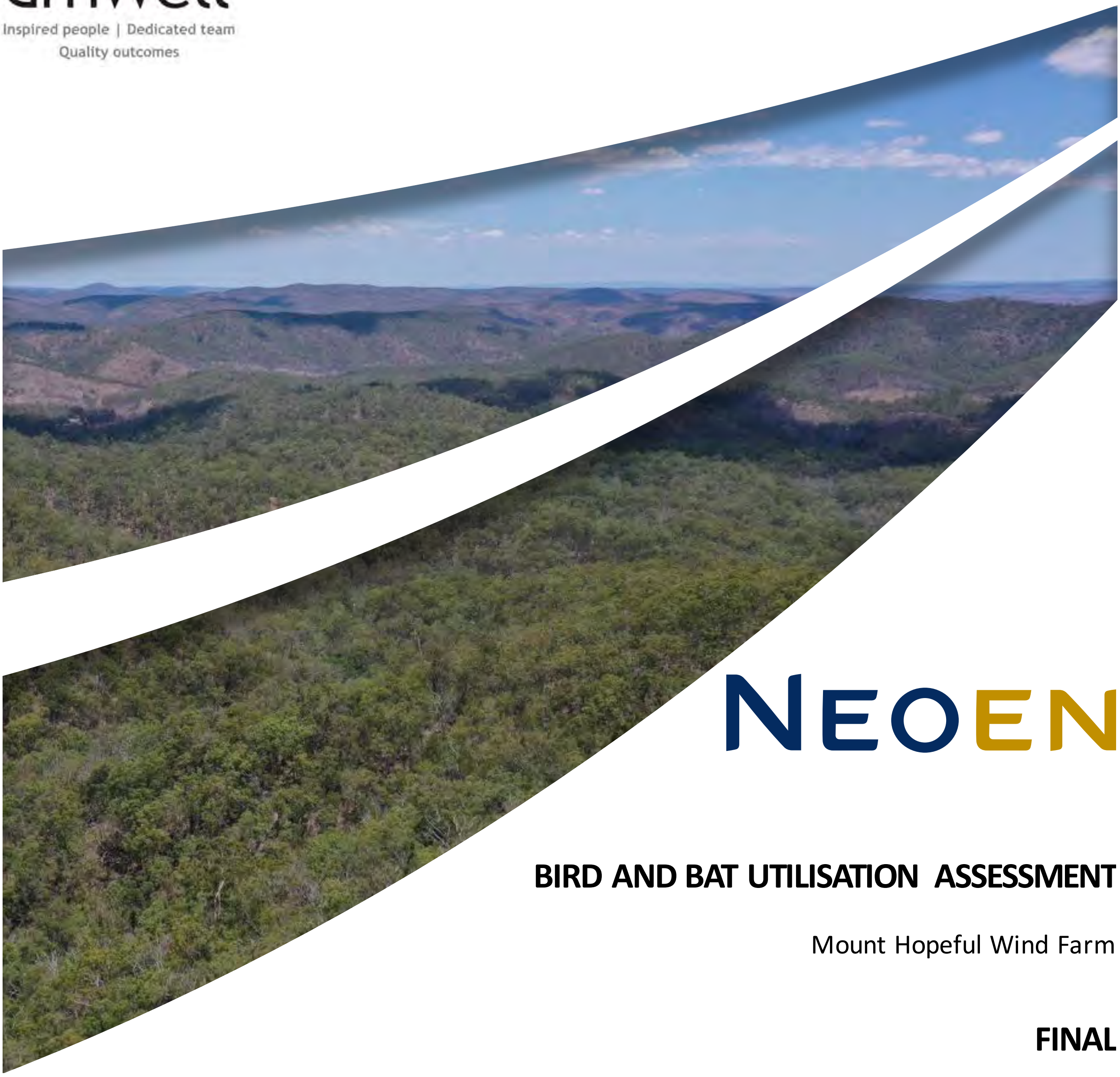
APPENDIX A

Bird and Bat Utilisation Assessment (Umwelt 2021)

umwelt

Inspired people | Dedicated team
Quality outcomes



NEOEN

BIRD AND BAT UTILISATION ASSESSMENT

Mount Hopeful Wind Farm

FINAL

November 2023

NEOEN

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Mount Hopeful Wind Farm

FINAL

Prepared by
Umwelt (Australia) Pty Limited
on behalf of
Neoen Australia Pty Ltd

Report No. 22753/R07/Appendix A
Date: November 2023

umwelt
Environmental & Social Consultants

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Abbreviations and Glossary

Abbreviations

Abbreviation	Description
AHD	Australian height datum
AGL	above ground level
BACI	before-after control-impact
BBAMP	Bird and bat adaptive management plan
BBUS	Bird and bat utilisation survey
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cth)
ha	hectares
km	kilometres
LGA	Local government area
m	metres
NC Act	*Nature Conservation Act 1992* (QLD)
Neoen	Neoen Australia Pty Ltd
Qld	Queensland
RSA	rotor swept area
Umwelt	Umwelt (Australia) Pty Ltd
WTG	Wind turbine generator

Glossary

Term	Meaning
Barotrauma	A phenomenon in which rapid air pressure changes cause tissue damage to air-containing structures, most notably the lungs of bats (Baerwald et al. 2008)
Biophysical	The biotic and abiotic surrounding of an organism or population
Blade Strike	A collision between bird or bat and wind turbine blade
Fecundity	The ability to produce an abundance of offspring
Interrelated	Related or connected to one another
Riparian	Relating to wetlands adjacent to rivers and streams.
Plateau	An area of fairly level high ground
Volant	Able to fly

1.0 Introduction

Umwelt was engaged by Neoen Australia Pty Ltd (Neoen) to undertake ecological surveys to support a development application for the proposed Mount Hopeful Wind Farm (the Project). This bird and bat utilisation assessment presents the methods and results of six dedicated bird and bat utilisation surveys, as well as bird and bat observations made during other flora and fauna field surveys, and an analysis of the findings with respect to potential impacts from the Project.

1.1 Scope of Works

The aims of this assessment are to document the bird and bat species that are present or likely to occur in the Study Area, and to assess the risk of impacts for species flying at rotor swept area (RSA), particularly those that are of conservation concern.

Specific objectives for the scope of work include:

- Determining the status of bird and bat species in the Study Area through review of existing data and field survey.
- Identifying which bird and bat species are susceptible to blade strike from wind turbines in the Study Area through analysis of flight behaviour recorded on site and assessment of external information.
- Assessing potential impacts of the Project on bird and bat species and estimating the relative level of risk associated with potential impacts on species that are considered most at risk.
- Outlining available measures that have been employed at wind farms to avoid or mitigate impacts of blade strike on birds and bats.

1.2 Project Description

The Mount Hopeful Wind Farm is located on the Ulam Range approximately 45 km south of Rockhampton, Queensland (Qld) and 65 km west of Gladstone, Qld (**Figure 1.1**). The Project involves the development of a wind farm that contains 63 wind turbine generators (WTGs, referred to herein as turbines), ancillary infrastructure including up to ten temporary and ten permanent wind monitoring masts, six substations, battery energy storage systems (BESS), temporary construction compound/laydown areas, a concrete batching plant, high voltage (275 kV) overhead powerlines, as well as underground power and communication cables. The Project is expected to have a maximum generation capacity of approximately 400 megawatts (MW).

At this stage in the Project, turbine specifications have not been confirmed by Neoen.

1.2.1 Study Area

The Study Area refers to the boundaries of the 17 freehold land parcels which encompass the infrastructure that has been designed for the proposed wind farm, as well as the boundary of the access road corridor (inclusive of the local road reserve for Glengowan Road, Playfields Rd and McDonalds Rd and small area of one additional adjacent land parcel) and a connection to the switching station in the road reserve at South Ulam Road. The area covers approximately 16,976 hectares (ha) and extends approximately 25 km north-south at the longest point and 42 km east-west at the widest point (this includes approximately 30 km of access road). The Study Area represents the limit of the vegetation and habitat mapped for the Project. It should be noted however, that this boundary does not represent the spatial bounds in which all Project field surveys have been conducted (this area being larger and including areas outside of the Study Area).

Lot and plans relevant to the Study Area include:

- Those relevant to the proposed wind farm:
  - 148/DS151, 2420/DT4077, 21/RN46, 30/RN72, 50/DT40144, 1933/RAG4058, 21/RN1345, 100/SP289441, 33/DT40123, 2039/RAG4056, 23/RN25, 38/DT40131, 2057/RAG4059, 24/RN34, 25/RN25, 15/RN1089 and 2345/DT4077.
- That relevant to the access road corridor:
  - 17/RAG4094.

Elevation within the Study Area ranges from approximately 500 m Australian Height Datum (AHD) to 120 m AHD, characterised by hilly terrain that comprises peaks and valleys, with areas of lower, generally flatter topography surrounding the Study Area to the east and west.

Major highways in proximity to the Study Area include the Bruce Highway to the east, Burnett Highway to the west, and the Dawson Highway to the south. These major transport corridors link to the cities of Rockhampton and Gladstone, as well as the Port of Gladstone from which the proposed turbine components will be transported.

The Study Area in the regional context is provided in **Figure 1.1**.

GDA 1994 MGA Zone 56

Legend

- Town
- Roads
- Railway
- Watercourses
- Local Government Area (LGA)
- Study Area
- Resources Reserve
- State Forest

FIGURE 1.1A

Study Area Mount Hopeful Wind Farm

Image Source: ESRI Basemap (2022) **Data source:** Department of Resources (2022)

Legend
- Town
- Roads
- Railway
- Watercourses
- Local Government Area (LGA)
- Study Area

FIGURE 1.1B

Study Area Mount Hopeful Wind Farm

Image Source: ESRI Basemap (2022) **Data source:** Department of Resources (2022)

1.2.2 Wind Turbine Dimensions

The Project proposes up to 63 turbines, with a maximum overall height (tip height) of 260 m above ground level (AGL). The turbines will have a horizontal axis, with a rotor consisting of three blades with a maximum blade length of up to 90 m and a maximum hub height of up to 180 m. The selected blade length and wind turbine hub height will be configured so that the tip height does not exceed 260 m. These maximum specifications are summarised in **Table 1.1.**

Table 1.1 Turbine Specifications

Feature	Maximum Specification
Project generation capacity	Approximately 400 MW
Turbine electrical output	Approximately 6.5 MW
Maximum number of turbines	63
Tip height	Up to 260 m
Blade length	Up to 90 m

** The specifications listed in the table are considered to be an upper limit and are intended to provide flexibility for any innovation in turbine design between now and the time of detailed design and construction.*

The rotor swept area (RSA) refers to the physical area swept by the rotating blades during operation. For a hub height of 145 m and blade length of 90 m, the RSA would be located at a height of between 55 m to 235 m AGL (**Figure 1.2a**), and for a hub height of 170 m and blade length of 90 m, the RSA would be between 80 m to 260 m AGL (**Figure 1.2b**).

For the purposes of data analysis for this report, an inclusive RSA of 55 to 260 m was considered.

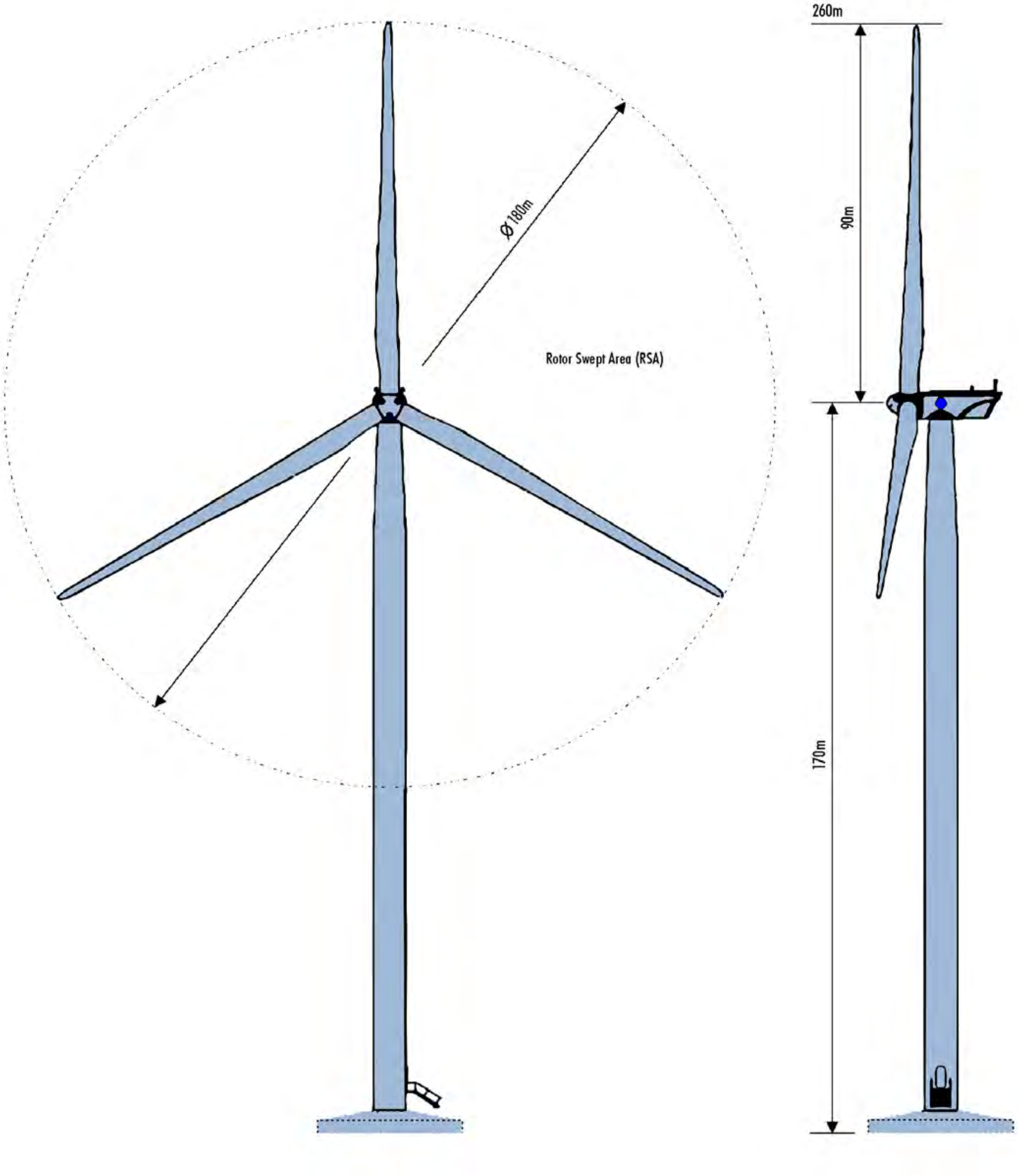


FIGURE 1.2A

Indicative Turbine Rotor Swept Area

Image Source: ESRI Basemap (2022) **Data source:** Department of Resources (2022)

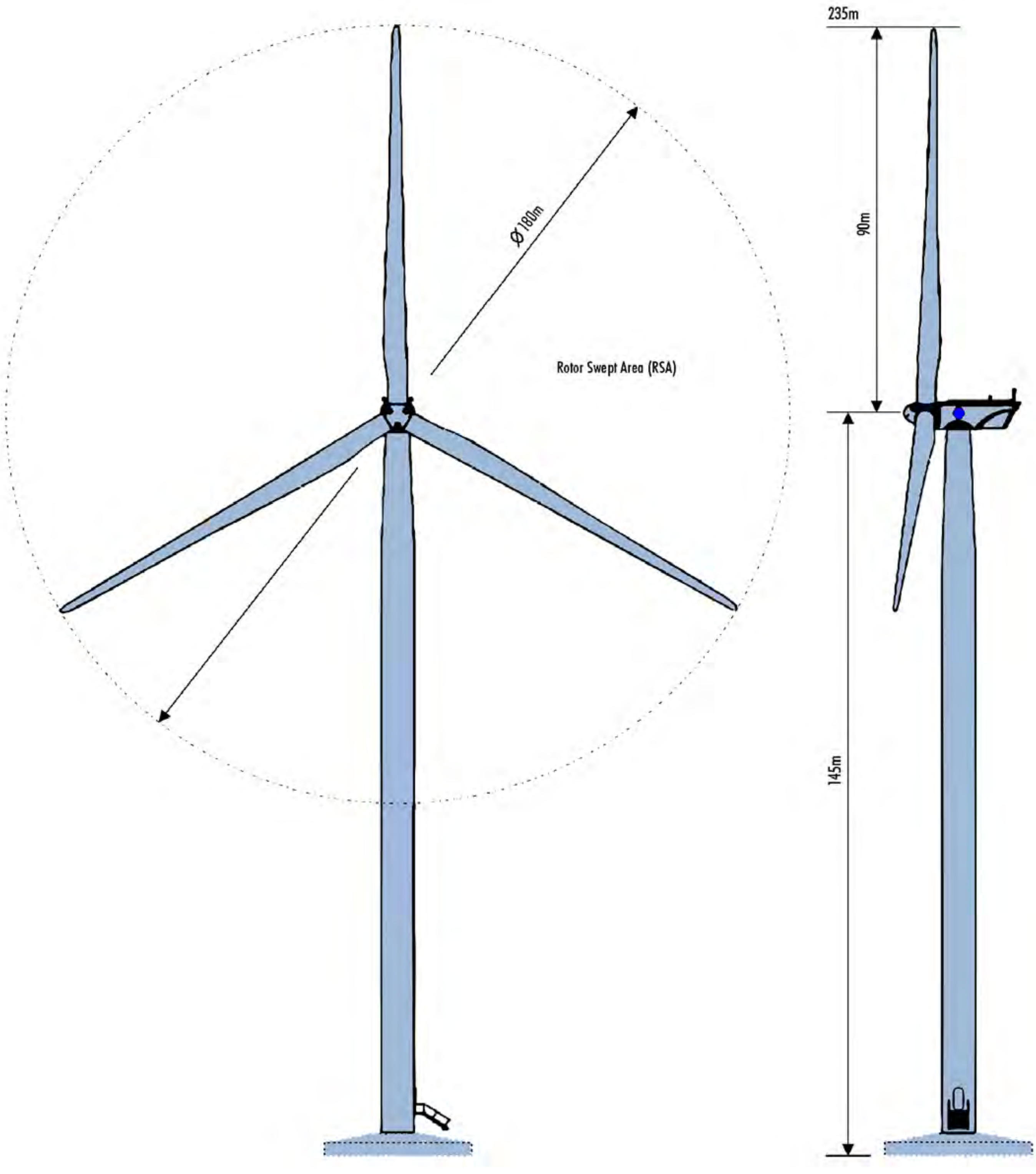


FIGURE 1.2B

Indicative Turbine Rotor Swept Area

2.0 Methods

2.1 Desktop Assessment

Tools used to investigate the potential occurrence of bird and bat species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and/or the *Nature Conservation Act 1992* (NC Act) (using a 10 km buffer around the Project boundary) included:

- EPBC Act Protected Matters Search Tool (PMST) (Department of Climate Change, Energy, the Environment and Water (DCCEEW) 2022).
- Wildlife Online search tool (Department of Environment and Science (DES) 2022).
- Spatial Portal (Atlas of Living Australia (ALA) 2022).
- Atlas and Birdata (BirdLife Australia 2022).

2.2 Field Survey

2.2.1 Survey Timing

Umwelt ecologists initially conducted bird utilisation surveys in 2019 during Winter (9 to 12 July 2019 and 7 to 12 August 2019) to establish vantage point locations and begin collecting a baseline avifaunal data set. The next surveys were conducted during 2020 in Autumn (23 February to 5 March 2020) and late Spring (5 to 12 November 2020). The timing of these surveys coincided with the seasonal migration of EPBC Act listed birds, including white-throated needletail (*Hirundapus caudacutus*) and fork-tailed swift (*Apus pacificus*).

Ecologists conducted additional bird utilisation survey in 2021 during Spring (8 to 15 October 2021) and 2022 during Summer (14 to 21 February 2022) to capture seasonal variation in birds present within the Project site and airspace. Additional Project associated surveys have been undertaken throughout this period recording bird species incidentally to capture threatened species records and contribute towards the broader understanding of avifaunal biodiversity across the Study Area.

Bird and bat utilisation surveys occurred in various months and seasons to best record species presence within the Study Area. The survey timing is as follows:

- July 2019 (Winter).
- February to March 2020 (Autumn).
- November 2020 (Spring).
- October 2021 (Spring).
- February 2022 (Summer).

Vantage point surveys were not undertaken during the July 2019 (Winter) survey. Bird and bat data collected during this survey was limited to the use of bat call detectors and incidental observations (recording flight data). The vantage point methodology as described in **Section 2.2.2** and **Section 2.2.3** was undertaken during the remaining four surveys.

A summary of the survey effort and timing of surveys has been outlined in **Appendix B**.

2.2.2 Bird Utilisation Survey

2.2.2.1 Vantage Point Surveys

Sixteen vantage survey points were selected on the ridgelines and peaks of the Study Area based on the degree of visibility of surrounding areas. The vantage survey points were configured such that representativeness and coverage of the Study Area was maximised. Four control sites (North 1, North 2, North 3 and North 4) were selected outside of the Study Area to inform the before-after control-impact (BACI) model. A further 12 vantage point locations were selected throughout the Study Area. The position of each vantage survey point is depicted in **Figure 2.1**. Photographs taken from each vantage survey point are presented in **Appendix A**.

Vantage point surveys were conducted to assess site utilisation and flight behaviour of bird species in the Study Area. Each site was surveyed for one hour during three sampling windows per day to minimise sampling bias. On each field trip, vantage points were surveyed twice during each sampling window such that individual surveys were undertaken on six occasions at each vantage point. The sampling windows are outlined below and tables detailing survey effort at each vantage point are presented in **Appendix B**.

- Morning (between 6.00 am and 10.00 am).
- Midday (between 10.00 am and 2.00 pm).
- Afternoon (between 2.00 pm and 6.00 pm).

During each vantage point survey, a single observer recorded the following information for each observation:

- Species and abundance.
- Observation type (visual or aural).
- Distance and direction from the observer (to the nearest 10 m and 10° respectively).
- Approximate height AGL of the observed bird/s (to the nearest 10 m).
- Direction of flight (to the nearest 10°).
- Flight pattern (i.e. not flying, local movement, directional flight, circling, swooping, varied, other).
- Behaviour (i.e. flight, foraging, perching, mating, aggressive interactions, hollow inspection, nesting, on station).

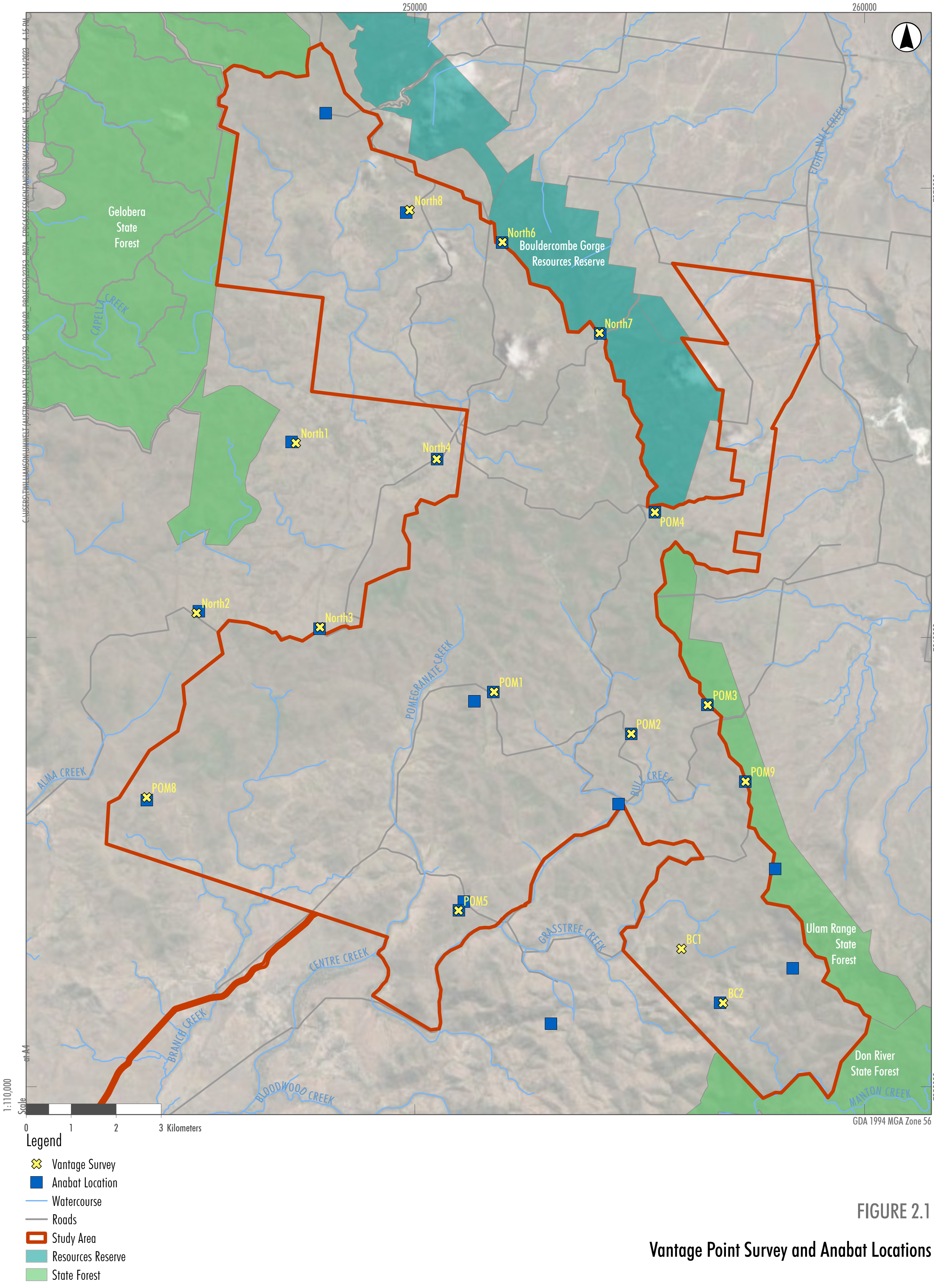


FIGURE 2.1

Vantage Point Survey and Anabat Locations

Image Source: ESRI Basemap (2020) Data source: QLD Government (2020)

2.2.2.2 Incidental Observations

Incidental bird observations were recorded at various locations throughout the Study Area during travel between vantage point sites. For each record the following were noted; species, location of the observation recorded, abundance, flight behaviour, flight height and flight direction. Additional incidental observations were recorded during other ecology field surveys conducted in July 2019, May to June 2020, October to November 2020, January 2021, October 2021 and October 2022. Incidental records of threatened species within 1.5 km of the Study Area buffer have been included in this assessment given the aerial nature of some species and the ability to traverse habitat across the Study Area.

2.2.3 Bat Utilisation Survey

Microchiropteran (microbat) echolocation calls were sampled using Anabat Swift recording devices at each vantage point location (**Figure 2.1**). Devices were placed approximately two metres AGL facing a cleared area or flyway and left for between two to five nights, and one Anabat Swift device was deployed at approximately 50 m AGL for three nights. Call data collected from each device was sent to Balance! Environmental for identification. Across all surveys, the total number of detector nights was 104. The number of sampling nights for each detector location is provided in **Appendix C**.

The likelihood that bat species detected in the Study Area fly at RSA height was based on literature relevant to the flight behaviour of recorded species. Where possible height information was inferred from calls detected from the elevated Anabat Swift device (approximately 50 m AGL upon met mast).

2.2.4 Field Survey Limitations

Ecologists aimed to survey all sites twice during each survey window which was largely achieved except for periods when inclement weather disrupted surveys. Vehicle incidents during February 2022 BBUS meant two vantage point could only be surveyed five times at the northern half of the Study Area and survey effort was largely concentrated within the midday and afternoon survey windows. Efforts were made to randomise the order of surveys across the whole Study Area, however the restricted access between the northern and southern halves of the Study Area meant that field surveys comprised two sampling efforts (north and south). Double counting of birds was managed by avoiding surveying the nearest vantage survey points concurrently such that observers were approximately three kilometres apart.

Ecologists were unable to determine exact numbers of birds present for aural observations, so for the purposes of this report and data analyses all aural observations will be assigned a count of one individual.

2.3 Likelihood of Occurrence Assessment

Given the rarity and/or potentially infrequent habitation of the Study Area by threatened or migratory species, it was necessary to complete a likelihood of occurrence assessment. The likelihood of occurrence of bird and bat species listed under the EPBC Act and/or the NC Act was determined through review of existing records, assessment of the suitability of vegetation in the Study Area for species known from the region, and observations made during field surveys.

Species were assigned to one of the following categories:

- **Known to Occur:** this category includes all species recorded in the Study Area in previous datasets or during Umwelt field survey.
- **High Potential to Occur:** This category includes species previously recorded in the immediate vicinity. The Study Area contains preferred habitat resources which may support a population of the species.
- **Moderate Potential to Occur:** The species is known from the broader area (desktop search extent) and some of the preferred habitat is present within the Study Area. Aerial foragers and other migratory birds that may overfly the Study Area are also included.
- **Low Potential to Occur:** The Study Area supports some suitable habitat, often marginal. The species may disperse through the Study Area infrequently and is unlikely to depend on the habitat for survival.
- **Unlikely to Occur:** This category includes those species for which the Study Area offers limited or no potential habitat, is outside their known range and/or is lacking broader habitat requirements.

Threatened bird and bat species listed under the EPBC Act which are Known to occur or have a Moderate or High likelihood of occurrence within the Study Area were included in the risk assessment.

2.4 Risk Assessment

2.4.1 Approach

The risk assessment considered the likelihood of species presence and conservation status of species observed or indicated to be present in the Study Area, as well as risk to observed species based on flight characteristics. Species that met any of the following criteria were included in the risk assessment:

a. Bird and bat species listed as threatened and/or migratory under the EPBC Act recorded in the Study Area or deemed to have a Moderate or High likelihood of occurrence in the Study Area.

b. Bird and bat species listed as threatened under the NC Act recorded in the Study Area or deemed to have a Moderate or High likelihood of occurrence in the Study Area.

c. Bird species recorded flying at RSA height in the Study Area.

d. bat species recorded in the Study Area that have Moderate to High potential to occur at RSA height.

2.4.2 Criteria for Estimating the Relative Risk of Blade Strike

The relative risk for assessed species was estimated using two criteria to ascribe likelihood of risk, and four criteria to ascribe consequence of risk (**Table 2.1** and **Table 2.2**). This method was employed in a recent study that aimed to develop a science-based approach to aid decision-making regarding turbine collision risk for birds and bats in Victoria (Lumsden *et al.* 2019).

Each criterion was either adopted unchanged or adjusted for the purposes of this assessment to ensure each was relevant to specific aspects of the Project, for example geographic location. For the purposes of this assessment, Criteria A, C and F were slightly altered, Criterion B was substantially altered, and the thresholds and spatial scale for Criterion E were adjusted.

Each species was ranked either low, moderate or high for each criterion depending on which was most appropriate in consideration of the assessed species' ecology and observed or predicted utilisation of the Study Area. Descriptions for each ranking are outlined in **Table 2.1** and **Table 2.2**. The approach used to assess each species against each criterion is described in **Appendix D**.

Table 2.1 Criteria Used to Ascribe Likelihood of Risk

A	B
Known or likely frequency of flights within RSA height	Status or frequency of occurrence in the Study Area.

Table 2.2 Criteria Used to Ascribe Consequence of Risk

C	D	E	F
Highly localised or concentrated population (for whole or part of lifecycle), such that siting of wind farm could have significant consequence to Queensland, national or international population	Impact on population relative to demographic capacity to replace fatalities (i.e., generalised combination of dispersal capacity of potential replacements, fecundity and generation time)	Known or estimated size of national or global population	Listed conservation status under the EPBC Act and/or the NC Act.

Each species was ranked either Low, Moderate or High for each criterion depending on which is most appropriate in consideration of the assessed species' ecology and observed or predicted utilisation of the Study Area. Descriptions for each ranking are outlined in (**Table 2.3**).

Criterion A (flight height) was assessed by identifying the frequency of flights observed between 55 m and 260 m in the Study Area and assessing this with consideration of observed and reported flight behaviour from elsewhere in Australia. Given that flight height data for bird and bat species in Australia is scant and observation data from pre-construction surveys at wind farms sites is largely unavailable, estimates of flight height require an adequate number of observations from the assessed site coupled with consideration of expert opinion on known flight behaviour for each species assessed. This Criterion is important as flight height is the primary variable through which a relative estimate of collision risk can be reached.

Criterion B (status in Study Area) was assessed by determining the status or estimating the frequency of occurrence in the Study Area. This Criterion is included as it is an essential component for estimating overall blade strike risk. In the absence of species observations, likelihood of occurrence was predicted based on historical and local observations, known ranges and/or presence of suitable foraging or nesting habitat.

Criterion C (geographic population concentration) was assessed by estimating the degree to which a species' population may be concentrated due to site related factors such as geographic location, habitat type, proximity to important habitat or roost locations (i.e., significant wetlands, roost caves) and how this relates to the specific landscape in which the Study Area is located. Lumsden *et al.* (2019) noted that this criterion is intended to account for situations where the degree to which a taxon is geographically concentrated may influence the risk posed by the particular location of a wind farm. Where large flocks or aggregations are involved the concentration of individuals may be for short seasonal periods but may nonetheless substantially heighten risk to a large portion of a species' total population. This is particularly important if a large proportion of a species' population passes through a localised area, such as a migratory corridor, over the course of each seasonal passage.

Criterion D (demographic resilience) was assessed through consideration of known aspects of each assessed species breeding biology and, most specifically, the nature of species' life-history traits. This criterion is included in the risk assessment as it is necessary to estimate the capacity to which a species may replace individuals lost to mortality resulting from blade strike.

Criterion E (population size) is included to account for the variation in the significance of mortality of a given number of individuals between species as a result of the large variation in assessed species' national or global populations. This, when assessed in combination with Criterion D provides a measure through which the relative vulnerability of a species to loss of individuals can be estimated.

Criterion F (listed conservation status) refers to the status of bird and bat species listed under the EPBC Act or the NC Act. In instances where a species listing differs between Acts, for example one that is listed vulnerable under the EPBC Act and endangered under the NC Act the most threatened listing category is selected for the purposes of this assessment. The order being critically endangered, endangered and vulnerable. Species listed as migratory and/or marine under the EPBC Act are not assigned a rank for this criterion.

Table 2.3 Descriptions of Each Ranking for Criterion A-F

Rank	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
	Likelihood of Risk		Consequence of Risk			
Low	Species that do not or rarely fly at RSA height.	Species that rarely occur in the Study Area.	Species that are widely distributed within areas of suitable habitat and the habitat itself is relatively widely dispersed.	Species that form breeding territories and that have a reasonable proportion of the population as nonbreeding 'floaters' that can rapidly replace breeding territorial adults if lost; species that may or may not form breeding territories and that are short-lived and have high fecundity; species that have capacity for long range or widespread juvenile or sub-adult dispersal.	Total population (i.e. whether that corresponds to the national population of Australian endemics or a migrant's global population) is estimated to number more than 20,000 individuals.	Species not listed or listed as near threatened or data deficient under the EPBC Act or the NC Act.
Moderate	Species which regularly fly below RSA height and occasionally fly at RSA height.	Species that occasionally occur in, or occasionally move through the Study Area.	Species that may be more widespread or have greater flexibility in the range of suitable habitat availability, but where a high proportion of their population is likely to be concentrated at sites where they do occur.	Species with life-history characteristics that sit between the low and high descriptions here.	Total population is estimated to number between 5,000 and 20,000 individuals.	Species listed as vulnerable under the EPBC Act or the NC Act.
High	Species in which a high proportion of flight activity is at RSA height.	Species that regularly occur in, or regularly move through the Study Area.	Bat species that have major aggregations at a few caves, or bird or bat species that have either very restricted distributions or those where a substantial proportion of a population may move through certain areas (i.e. migratory pathways).	Species that form breeding territories but where there is limited capacity for a lost breeding adult to be readily replaced; species that do not form breeding territories and that are long-lived and/or have low fecundity; species that may have short-distance juvenile or sub-adult dispersal capacity only.	Total population is estimated to number less than 5,000 individuals.	Species listed as endangered or critically endangered under the EPBC Act or the NC Act.

2.4.3 Estimating Overall Risk

Estimates of overall risk for each assessed species were determined by following an approach similar to that employed by Lumsden *et al*. (2019) with the most notable exception being the difference in spatial scale for which resulting estimates of risk are intended to be relevant to (i.e. state-wide vs site-specific). Elements of the likelihood and consequence of collision were combined to form an overall qualitative risk category (Low/Moderate/High) specific to the Project for the likelihood of collision and the consequence of collision. Likelihood of collision questions (Criterion A and B) and consequence of collision questions (Criterion C to F) were combined in a generally additive process to determine whether the overall likelihood and consequence of collisions was Low, Moderate or High. The following describes how the **likelihood of collision** was determined:

- **High**: Either criteria A or B is High and neither can be Low.
- **Moderate**: All other combinations not described in High or Low.
- **Low**: Both criteria A and B are Low, or:
  - In cases where criterion A is Low because the likelihood of flight at RSA is deemed highly unlikely based on knowledge of the species' flight behaviour and/or observations from the Study Area.
  - In cases where criterion B is Low because the likelihood of occurrence is deemed very unlikely based on the distribution of the species, expert advice and / or supported by literature or records.

The following describes how the **consequence of collision** was determined:

- **High:** The majority of criteria C through F are High, or the risk associated with criterion C for localised concentration is High. It was considered that the consequences of high mortality due to wind turbine collisions for species that have a limited distribution and/or have the capacity to be highly concentrated is sufficiently large such that, if a species' risk associated with this element was High, the consequences of collision should also be set to High, irrespective of the risks of the other criteria.
- **Moderate**: The majority of criteria C through F were Moderate.
- **Low:** The majority of criteria C through F were Low.

In cases where risk achieved two of two criteria, the higher risk rating was designated, e.g., two Moderate and two High criteria would result in a High rating.

Once the overall risk levels for the likelihood and consequence of collision specific to the Project had been assigned for a species, the results were then placed into a risk matrix to determine the level of concern (**Table 2.4**). Five categories of risk were used, namely Negligible, Low, Moderate, High, and Very High, based on the combination of the scores for likelihood and consequence.

Table 2.4 Risk matrix

		Consequence of Collisions		
		Low	Moderate	High
Likelihood of Collisions	Low	Negligible	Minor	Moderate
	Moderate	Minor	Moderate	High
	High	Moderate	High	Very High

2.4.4 Collision Risk Modelling for White-throated Needletail

Collision risk modelling for white-throated needletail was assessed by Biosis Pty Ltd (Biosis) using their Deterministic Collision Risk Model (refer to Appendix B of Attachment G (Bird and Bat Adaptive Management Plan) of the Preliminary Documentation). The collision risk model accounts for the bird flight data that occurs within the heigh area occupied by wind turbines. Flight data collected during BBUS (**Section 2.2.2**) was used as an empirical sample for the model to extrapolate the number of flights that may occur over a 12-month period.

2.4.4.1 Overview of the Model

As per the collision risk modelling (Appendix B of Attachment G (Bird and Bat Adaptive Management Plan) of the Preliminary Documentation) the model categorises turbines into a static and dynamic components. The entire turbine (including the tower, nacelle and the rotor when stationary) represents the static component. The dynamic component is the volume swept by the leading edge of the rotor blades in the time it takes the species of interest to pass through the airspace in which the rotor sweeps.

Since the turbine tower below rotor swept height is always a static component and poses minimal collision risk, the model takes this into account by dividing flights into those below turbine rotor height, and those within the height zone swept by turbine rotors and allocates different risk rates to these height zones.

The risk assessment accounts for a combination of variables that are specific to the proposed wind farm and to data for birds from the site. They include the following:

- The numbers of flights of the species below rotor height, and for which just the lower portion of turbine towers may present a collision risk.
- The numbers of flights at heights within the zone swept by turbine rotors, and for which the upper portion of towers, nacelles and rotors present a collision risk.
- The numbers of bird movements-at-risk, as recorded during timed point counts, extrapolated to determine an estimated number of movements-at-risk the species makes in an entire year. Account is taken of the portion of the year that birds may be present in Australia, and they may thus be at risk. The mean area (m^2 per turbine), of tower, nacelle and stationary rotor blades of a wind generator that present a risk to birds. Thus, the mean area presented by a turbine is between the maximum (where the direction of the bird is perpendicular to the plane of the rotor sweep) and the minimum (where the direction of the bird is parallel to the plane of the rotor sweep). The mean presented area is determined from turbine specifications supplied to Biosis for the specific make and model of turbine. It represents the average area presented to an incoming flight from any direction.

- The additional area (m^2 per turbine) presented by the movement of rotors during the potential flight of a bird through a turbine. This information is determined via a calculation involving species-specific, independent parameters of flight speed and body length and supplied turbine specifications.
- The model assumes that all turbines at the site represent equal risk.
- A calculation of the average number of turbines a bird is likely to encounter in a given flight through the site. This is based on the scattered configuration of turbines in the landscape and the total number of turbines proposed for the project.

2.4.4.2 Avoidance Rate

Results are provided based on various avoidance rates for white-throated needletail. The avoidance rate is the capacity for a bird to avoid a collision, whether that occurs due to a cognitive response on the part of a bird or not. An avoidance rate of 0.95 would equate to one flight in 20 in which a bird takes no action to avoid a turbine and a 0.999 avoidance rate equates to one flight in 1000 in which it would not avoid a turbine.

It should be noted that internationally there is very little empirical evidence for the actual avoidance rate for any bird species and for this reason it is prudent to provide a range of estimates that are considered to be reasonable. The evidence that is available suggests that avoidance capacity is species-specific, and that the great majority of birds have avoidance capability that is higher than 0.98. Overseas avoidance rates of greater than 0.99 have been demonstrated to be applicable to a variety of seabirds (Cook et al. 2014).

Based on experience with a wide range of bird species, it is certain that virtually all species have high capacity to avoid collision with the static components of turbines. White-throated needletails are highly agile, aerial birds and it is not considered likely that they would collide with stationary turbines. For this reason, an avoidance rate of 0.999 has been applied to static turbine components in the modelling regardless of the different dynamic avoidance rates applied. Various avoidance rates are modelled for the dynamic turbine components because, while it is reasonable to assume that White-throated Needletails can avoid a moving rotor most of the time, the actual rate at which they can do so is not certain. For this reason, results are provided for 0.990, 0.995 and 0.999 avoidance rates for the dynamic components (moving rotor) of turbines.

2.4.4.3 Result Metrics

Bird movement data was measured by the number of flights recorded at the site. Only when a reasonable estimate can be made for the number of individuals that might occur at the site can the model incorporate that to provide results expressed as an annual estimate of the number of individuals that might collide (otherwise the results remain expressed as the simple number of flights at risk). In order to provide results in terms of an annual estimate of bird collisions, a site-population estimate for white-throated needletails has been applied for the present modelling.

The model cannot forecast the frequency of collisions around the predicted annual average, and it is important to recognise that the number of any actual collisions that might occur can be expected to vary from year to year in a distribution around the average.

All results are provided to three significant figures simply to permit differences between them to be apparent. This should not be taken to indicate a measure of precision in result values. Output values represent annual 'average' results and, of course actual bird fatalities will always be measured in numbers of individuals and that may vary from year-to-year in a distribution around the mean.

3.0 Results

3.1 Desktop Assessment

Review of database searches identified 30 threatened and/or migratory bird species and 4 threatened bat species that have the potential to occur within the Study Area. These results were combined with field observations to develop the Likelihood of Occurrence Assessment (**Section 3.3**) and Risk Assessment (**Section 3.4**).

3.2 Field Survey

3.2.1 Site Conditions

Weather conditions throughout the BBUS field program varied between surveys due to seasonal variation in temperature, wind direction and wind speed. The lowest minimum temperature was recorded during the winter 2019 BBUS with 4.4 °C recorded on the last day of the survey (12/08/2019). Temperature peaked during the spring 2020 BBUS with a maximum temperature of 35.2 °C recorded on 6/11/2020. Wind rose data from the Rockhampton Aero Australian Bureau of Meteorology (BOM) station (039083) during the survey months indicates that the predominant prevailing wind direction for the Study Area trends from the south-east with little overall variation between wind direction from 9 am to 3 pm. Wind speeds throughout the survey program were consistently high with the highest recorded wind speeds at both 9 am and 3 pm of 26 km/h. The lowest wind speeds recorded during the surveys were 2 km/h at 9 am on 12/10/21 and 7 km/h at 9 am on 28/02/2020.

Weather conditions recorded at the Rockhampton Aero (039083) during the surveys are presented in **Appendix E**.

3.2.2 Bird Utilisation Survey

3.2.2.1 Species Diversity

A total of 137 bird species were recorded within the Study Area during the BBUS field program. A further 18 bird species have been recorded within the Study Area during other Project associated fauna surveys. A list of all species recorded at each location is presented in **Appendix F**.

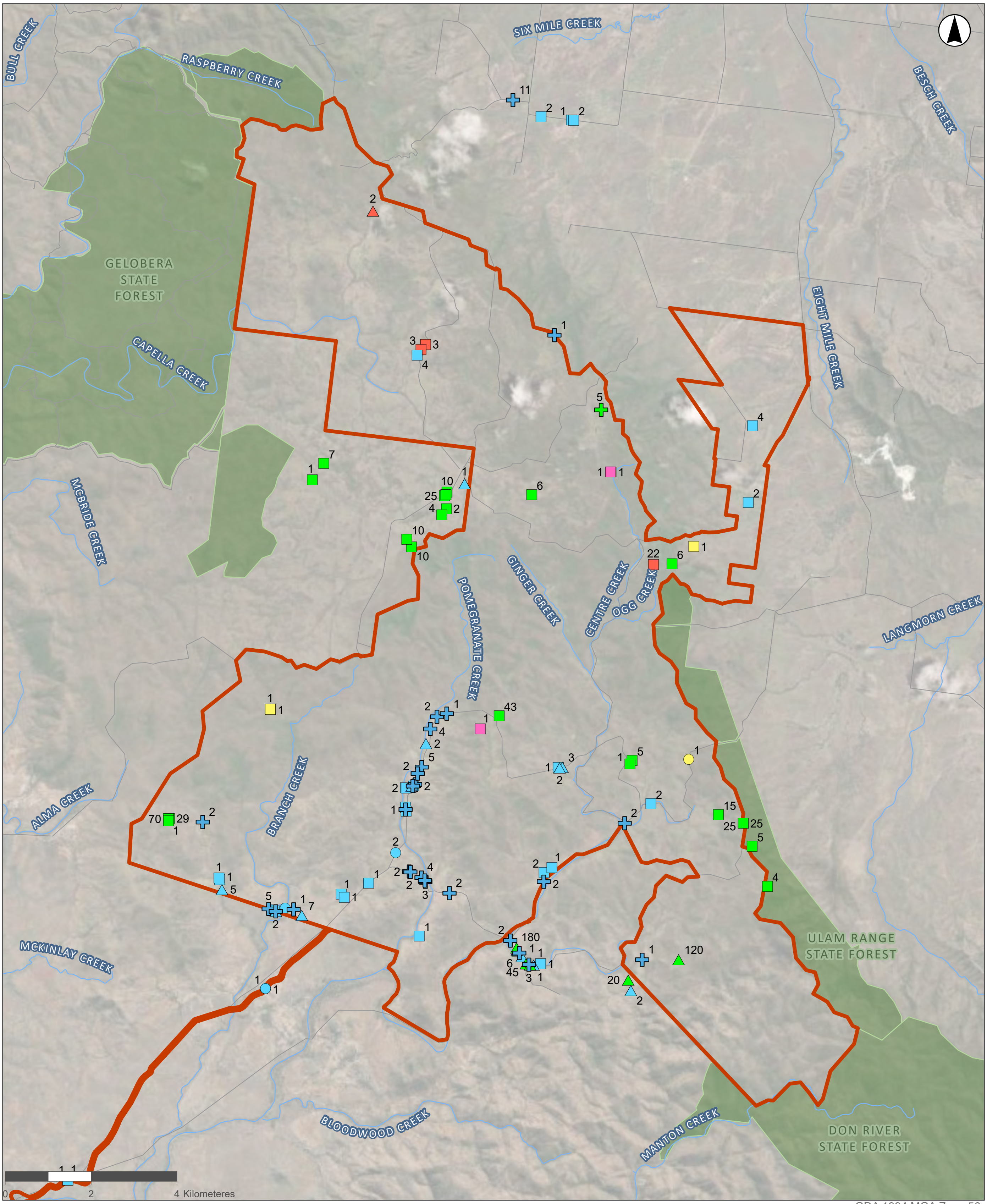
Of the bird and bat species identified within the Study Area, five are listed as threatened or migratory under the NC Act and/or the EPBC Act. These are detailed in **Table 3.1** and illustrated in **Figure 3.1**.

Table 3.1 Listed Threatened and Migratory Species Recorded During All Surveys

Common Name	Scientific Name	NC Act Listing	EPBC Act Listing
glossy black-cockatoo	*Calyptorhynchus lathami*	Vulnerable	-
rufous fantail	*Rhipidura rufifrons*	Special Least Concern	Migratory
spectacled monarch	*Symposiachrus trivirgatus*	Special Least Concern	Migratory
squatter pigeon (southern)	*Geophaps scripta scripta*	Vulnerable	Vulnerable
white-throated needletail	*Hirundapus caudacutus*	Vulnerable	Vulnerable; Migratory

Glossy Black-cockatoo

Glossy black-cockatoo was recorded on five occasions, once during the bird utilisation survey where a flock of 22 were observed transiting south from the POM4 vantage point along the eastern ridge of the Study Area between 60 to 90 m AGL. The remaining four observations were of small flocks (two–three individuals), with one group foraging within a stand of *Allocasuarina torulosa*.



1:125,000 Scale at A4

GDA 1994 MGA Zone 56

Legend

- Watercourse
- Roads
- Study Area
- State Forest

Threatened Bird Species

2019

- Squatter pigeon (southern) (*Geophaps scripta scripta*)
- Rufous fantail (*Rhipidura rufifrons*)

2020

- Glossy black-cockatoo (*Calyptorhynchus lathami erebus*)
- Squatter pigeon (southern) (*Geophaps scripta scripta*)
- White-throated needletail (*Hirundapus caudacutus*)
- Spectacled monarch (*Symposiachrus trivirgatus*)
- Rufous fantail (*Rhipidura rufifrons*)

2021

- Glossy black-cockatoo (*Calyptorhynchus lathami erebus*)
- Squatter pigeon (southern) (*Geophaps scripta scripta*)
- White-throated needletail (*Hirundapus caudacutus*)

2022

- Squatter pigeon (southern) (*Geophaps scripta scripta*)
- White-throated needletail (*Hirundapus caudacutus*)

FIGURE 3.1A

Threatened and Migratory Species Locations

Image Source: ESRI Basemap (2022) **Data source:** Department of Resources (2022)

Legend
- Watercourse
- Roads
- Study Area
- State Forest

Threatened Bird Species

2019
- Squatter pigeon (southern) (*Geophaps scripta scripta*)

2020
- Squatter pigeon (southern) (*Geophaps scripta scripta*)
- White-throated needletail (*Hirundapus caudacutus*)

2021
- Squatter pigeon (southern) (*Geophaps scripta scripta*)

2022
- Squatter pigeon (southern) (*Geophaps scripta scripta*)

FIGURE 3.1B

Threatened and Migratory Species Locations

Image Source: ESRI Basemap (2022) **Data source:** Department of Resources (2022)

Rufous Fantail

Rufous fantail was only recorded incidentally and not during vantage point surveys, as such no flight data were recorded. Of four observations, three were made on the western edge of the Study Area, while the remaining observations occurred along the eastern boundary of the Study Area.

- One individual observed actively foraging within a narrow gully, comprising a structurally complex lower tree and shrub layer. The gully was situated adjacent to steep sloping Eucalypt woodland.
- One individual observed within vine thicket vegetation, comprising structurally complex shrub layer over ground microhabitat of fallen logs and course litter.
- Two individuals were recorded on separate occasions on steep slopes, dispersing through eucalypt woodland in close proximity to vine thicket vegetation and in areas invaded by *Lantana camara*.

On all occasions, the rufous fantail was using lower portions of habitat, occupying the ground and mid-stratum vegetation layers (i.e., below RSA).

Spectacled Monarch

Spectacled monarch was observed only twice incidentally during June 2020 in other ecological surveys, however the observations were made over 6 km apart, once in the central portion and once in the north-eastern portion of the Study Area. On both occasions the species was observed in the mid-statum vegetation layers.

Habitat suitable for foraging and dispersal was present within the Study Area and included the following:

- semi-evergreen vine thicket
- gullies in eucalypt woodlands where dense vegetation occurs.

The species utilises this region on its' migration and does not reside or breed in the region. As such habitat within the Study Area has been identified as foraging and dispersal only (i.e., below RSA).

Squatter Pigeon (Southern)

Squatter pigeon was observed on 78 occasions, throughout the field survey program, although this is likely to include multiple observations of the same individuals. It was commonly recorded along access tracks in non-remnant areas of the Study Area and was observed using a range of habitat types. All observations were made incidentally with 55.1% of observations based on one individual, however groups of up to 11 individuals were observed, often within close proximity to water sources.

Water sources suitable for the foraging of the squatter pigeon (southern) do not occur commonly within the Study Area. Stream order 1 and 2 watercourses occur extensively, however are associated with rugged and steep terrain areas generally at elevation. Farm dams identified using the Department of Resources (DoR) Reservoirs dataset were all considered suitable and are likely to be the primary resource utilised by the species due to their permanency.

On all occasions the species was observed on the ground or perched upon infrastructure (farm gates). When flushed, squatter pigeon was infrequently observed flying onto a nearby tree perch, no taller than 6 m (below RSA).

White-throated Needletail

White-throated needletail were observed on 30 occasions, 21 of which were incidental. Observations were variable in abundance and behaviour, with some individuals transiting through the airspace, however the majority of observations were of larger flocks (1 to 180) circling between 5 to 400 m AGL. White-throated needletail are further discussed in **Section 3.2.2.3**.

3.2.2.2 Species by Record and Count

Fifty-four species were recorded frequently (i.e., >10 times) throughout all field surveys, both during vantage point surveys and incidentally. **Table 3.2** outlines the 10 most recorded (visually and aurally) bird species. Pied currawong, rainbow lorikeet and Torresian crow were all recorded at every vantage point and incidentally, often observed in-flight or heard calling from a distance.

Table 3.2 Top 10 Species by Record

Rank	Common Name	Scientific Name	Total Observations
1	pied currawong	*Strepera graculina*	228
2	rainbow lorikeet	*Trichoglossus moluccanus*	161
3	Torresian crow	*Corvus orru*	161
4	white-throated honeyeater	*Melithreptus albogularis*	128
5	wedge-tailed eagle	*Aquila audax*	125
6	Australian magpie	*Gymnorhina tibicen*	109
7	noisy friarbird	*Philemon corniculatus*	108
8	laughing kookaburra	*Dacelo novaeguineae*	107
9	striated pardalote	*Pardalotus striatus*	91
10	squatter pigeon (southern)	*Geophaps scripta scripta*	78

Table 3.3 outlines the top 10 species by count, calculated using visual observations made both during vantage point surveys and incidentally. White-throated needletail was commonly observed in large flocks of up to 180, topknot pigeon was observed on only three occasions in flocks of 60 to 100, while rainbow lorikeet was observed frequently as individuals or pairs, with occasional observations of flocks (up to 39 individuals).

Table 3.3 Top 12 Species Observed Visually by Count

Rank	Common Name	Scientific Name	Total Count (Visual)
1	Torresian crow	*Corvus orru*	864
2	white-throated needletail	*Hirundapus caudacutus*	698
3	rainbow lorikeet	*Trichoglossus moluccanus*	337
4	pied currawong	*Strepera graculina*	261
5	topknot pigeon	*Lopholaimus antarcticus*	222

Rank	Common Name	Scientific Name	Total Count (Visual)
6	wedge-tailed eagle	*Aquila audax*	170
7	white-throated honeyeater	*Merops ornatus*	164
8	rainbow bee-eater	*Trichoglossus moluccanus*	163
9	noisy friarbird	*Philemon corniculatus*	160
10	squatter pigeon	*Geophaps scripta scripta*	143

3.2.2.3 At-risk Species

Twenty-four bird species were observed flying within the RSA, placing them at risk of turbine blade strike. A summary of these species and their minimum and maximum flight heights are presented in **Table 3.4**.

Table 3.4 At-risk Species

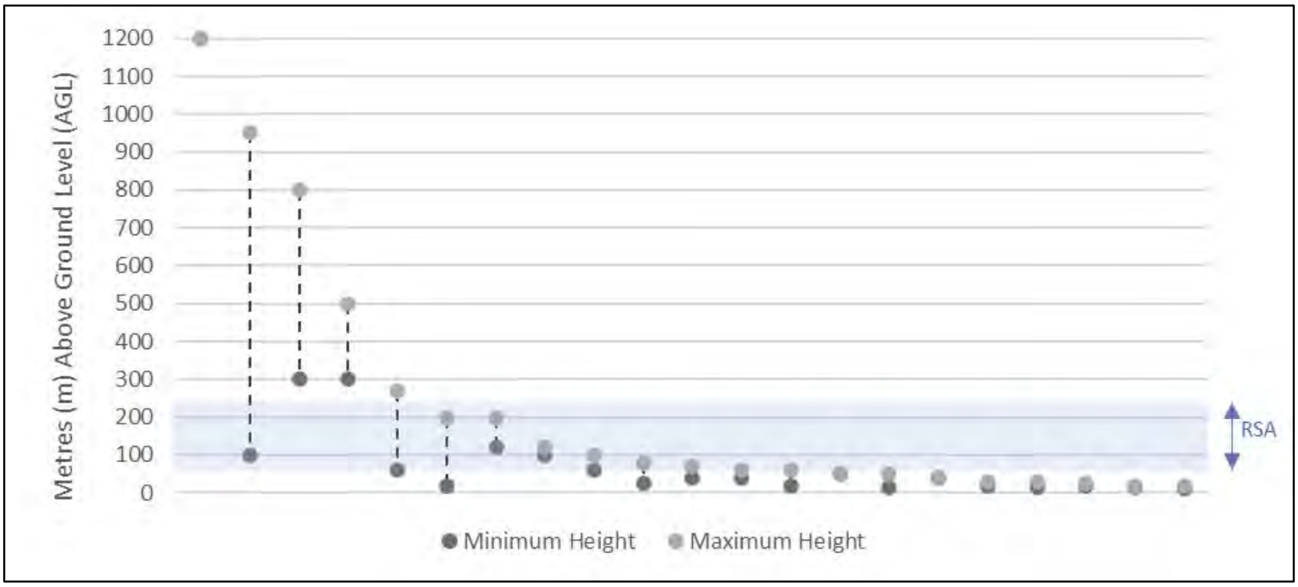
Common Name	Scientific Name	Observed Flight Height	
		Minimum	Maximum
Australian magpie	*Gymnorhina tibicen*	0	700
black kite	*Milvus migrans*	200	300
blue-faced honeyeater	*Entomyzon cyanotis*	10	120
brown falcon	*Falco berigora*	10	1200
brown goshawk	*Accipiter fasciatus*	14	200
channel-billed cuckoo	*Scythrops novaehollandiae*	6	1000
galah	*Eolophus roseicapilla*	80	80
glossy black-cockatoo	*Calyptorhynchus lathami*	20	90
nankeen kestrel	*Falco cenchroides*	0	300
noisy friarbird	*Philemon corniculatus*	0	80
pacific baza	*Aviceda subcristata*	10	190
peregrine falcon	*Falco peregrinus*	10	700
pied currawong	*Strepera graculina*	0	130
rainbow bee-eater	*Merops ornatus*	5	120
rainbow lorikeet	*Trichoglossus moluccanus*	1	300
red-tailed black-cockatoo	*Calyptorhynchus banksii*	20	100
scaly-breasted lorikeet	*Trichoglossus chlorolepidotus*	30	60
sulphur-crested cockatoo	*Cacatua galerita*	10	1200

Common Name	Scientific Name	Observed Flight Height	
		Minimum	Maximum
topknot pigeon	*Lopholaimus antarcticus*	80	500
Torresian crow	*Corvus orru*	0	800
tree martin	*Petrochelidon nigricans*	10	250
wedge-tailed eagle	*Aquila audax*	10	1500
whistling kite	*Haliastur sphenurus*	200	300
white-throated needletail	*Hirundapus caudacutus*	1	1100

Six at-risk species are highlighted due to the frequency of observed flights within the RSA, total count, and/or their status as a listed threatened or migratory species, including brown falcon, rainbow lorikeet, sulphur-crested cockatoo, Torresian crow, wedge-tailed eagle and white-throated needletail. A summary of observations for these species are discussed below.

Brown Falcon

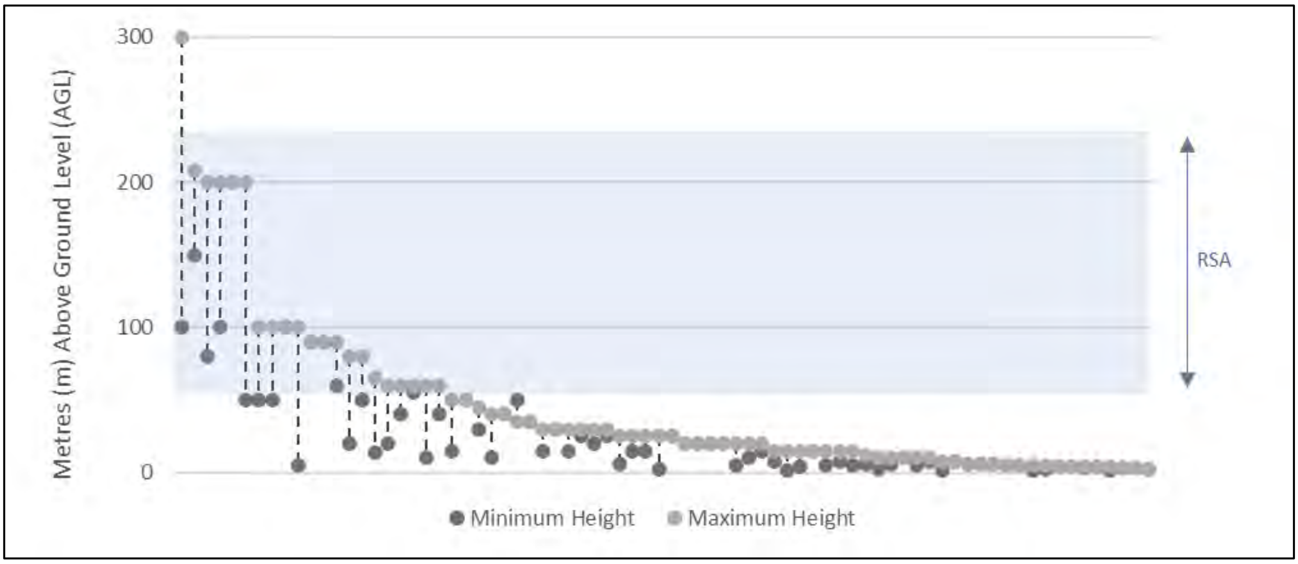
Brown falcon were recorded on 34 occasions (most commonly solitarily) of which 21 records were made across all surveys where flight data was recorded (**Graph 3.1**). 42.9% of flights observed were within the RSA.



Graph 3.1 **Brown Falcon minimum and maximum heights recorded during the BBUS program**

Rainbow Lorikeet

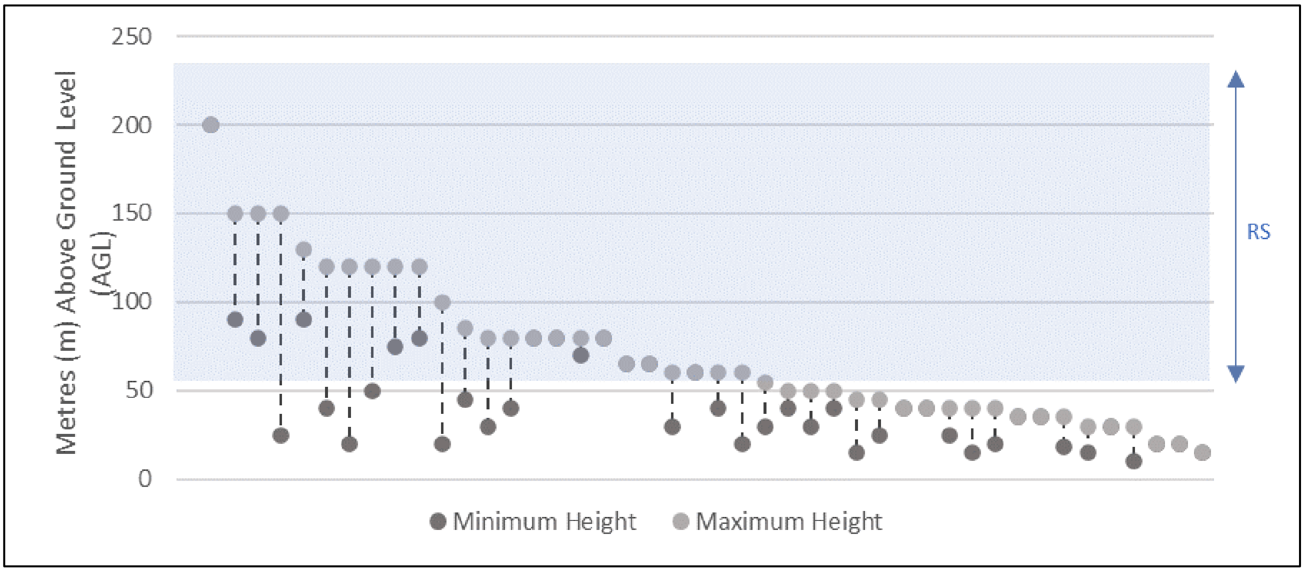
Rainbow lorikeet were recorded on 161 occasions; 76 instances during all surveys of which 47.2% were visual observation of rainbow lorikeets transiting through the Study Area airspace; 27.6% of these observed flights were within the RSA (**Graph 3.2**). Most observations were of indivuals, pairs and small flocks (up to seven lorikeets), though one flock of 39 was recorded.



Graph 3.2 **Rainbow Lorikeet minimum and maximum heights recorded during the BBUS program**

Sulphur-crested Cockatoo

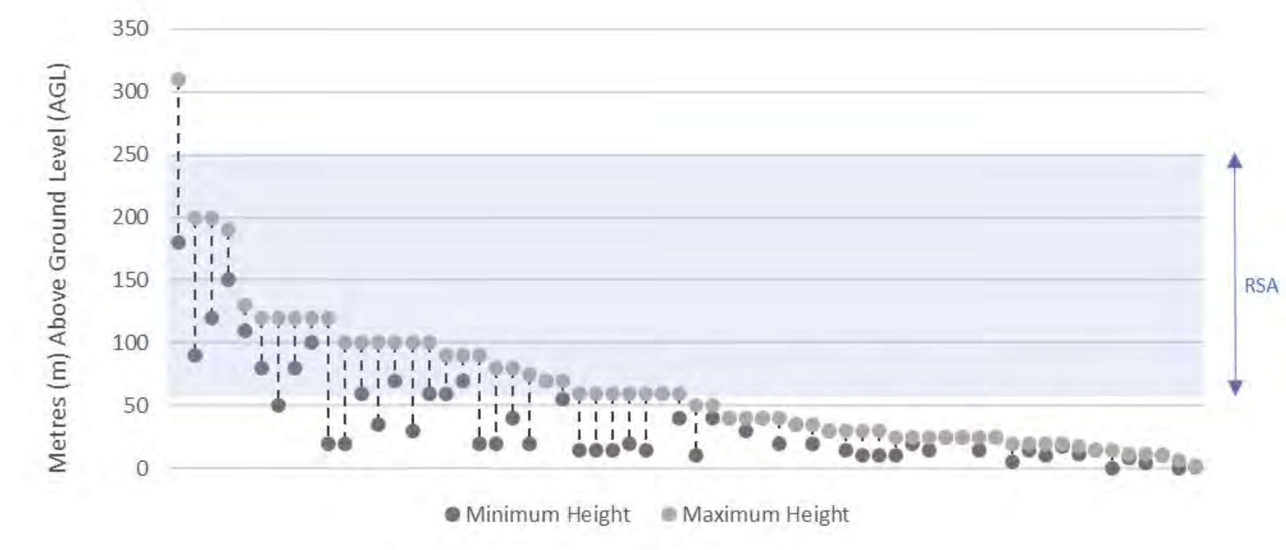
Sulphur-crested cockatoo were recorded on 78 occasions, 45 instances during all surveys of which 57.7% were visual records across all surveys where birds were observed transiting through the Study Area airspace; 55.6% of those flights were in the RSA (**Graph 3.3**). Most records were of individuals, though pairs and flocks of up to eight cockatoos were recorded. Sulphur-crested cockatoo were recorded at a height of 600 m to 1200 m, this flight height is not included in **Graph 3.3** to better display flight heights within the RSA.



Graph 3.3 **Sulphur-crested cockatoo minimum and maximum heights recorded during the BBUS program**

Torresian Crow

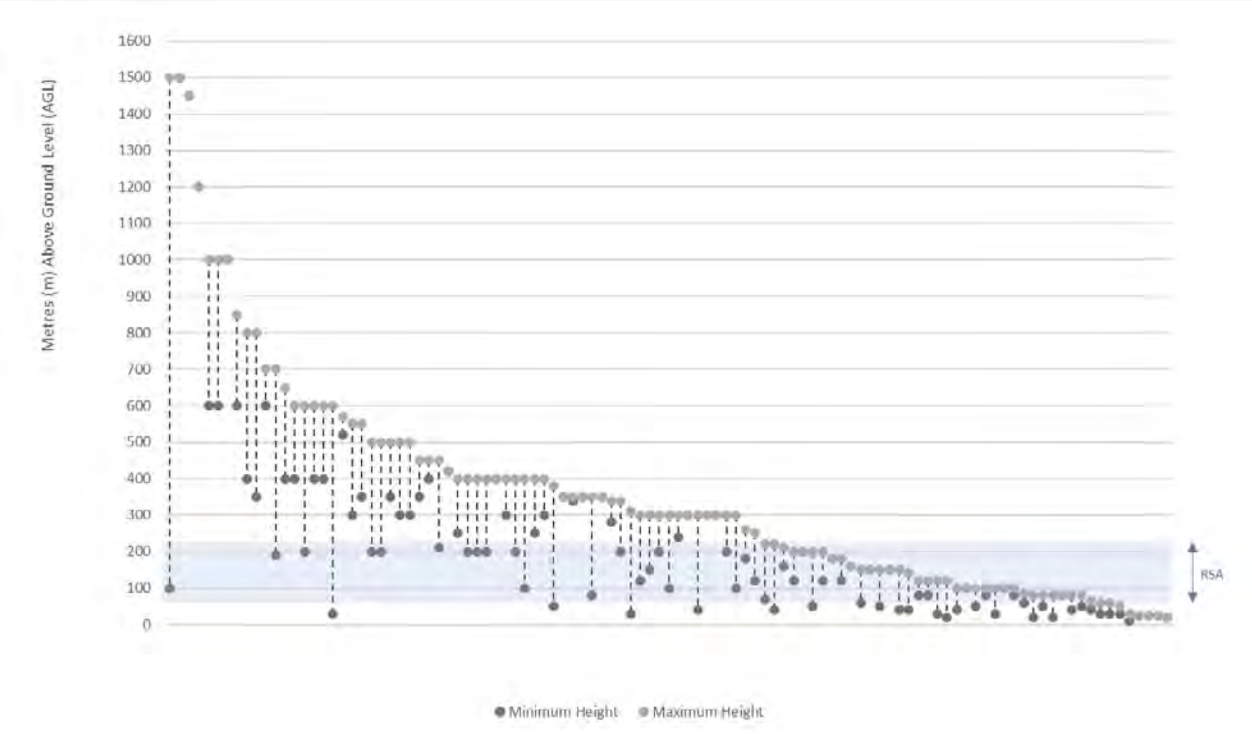
Torresian crow were observed on 161 occasions, 63 instances during all surveys of which 31.9% were visual records across all surveys where most commonly as individuals with some observations of pairs and small flocks (up to 16 individuals). 49.2% of visual observations made during all surveys were of crows transiting the Study Area air space through the RSA (**Graph 3.4**). Torresian crow were recorded at a height of 800 m, this flight height is not included in **Graph 3.4** to better display flight heights within the RSA.



Graph 3.4 Torresian crow minimum and maximum heights recorded during the BBUS program

Wedge-tailed Eagle

Wedge-tailed eagle were observed on 125 occasions across all surveys, usually solitarily or in pairs, with two observations of small flocks (three and four eagles). 64.5% of wedge-tailed eagles of observations involved birds circling through the Study Area air space, with the remaining 35.5% transiting overhead. 63% of these observations involved flight within the RSA (**Graph 3.5**).



Graph 3.5 **Wedge-tailed eagle minimum and maximum heights recorded during the BBUS program**

White-throated Needletail

White-throated needletail was recorded on 30 occasions flying over a diversity of habitat types, both incidentally and during BBUS. A total of 698 individuals have been recorded during surveys with a total of 324 individuals recorded at vantage points during BBUS and a total of 374 individuals recorded incidentally across all survey events. The number of individuals observed in aggregations ranged from one to 180. During the morning BBUS survey period (6 am to 10 am) a total of 413 individuals were recorded. During the midday BBUS survey period (10 am to 2 pm) a total of 236 individuals were recorded. During the afternoon BBUS survey period (2 pm to 6 pm) a total of 49 individuals were recorded.

A summary of the white-throated needletail records made throughout the field survey program is provided in **Table 3.5.**

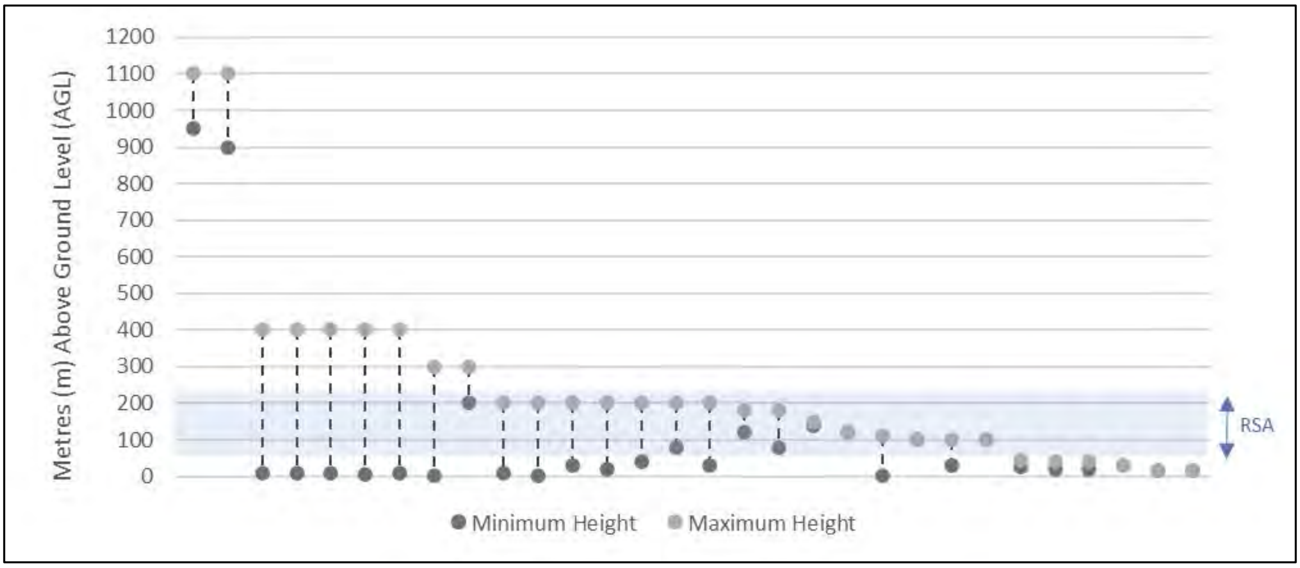
Table 3.5 **White-throated Needletail Records**

Date	Survey Period	Latitude (GDA94)	Longitude (GDA 94)	Count
28/02/2020	Morning (6 am–10 am)	-23.883207	150.486404	70
29/02/2020	Morning (6 am–10 am)	-23.88362202	150.4866362	29
29/02/2020	Morning (6 am–10 am)	-23.88349405	150.4865347	1
29/02/2020	Morning (6 am–10 am)	-23.827547	150.59845	6
3/03/2020	Morning (6 am–10 am)	-23.81588274	150.5512635	10
3/03/2020	Morning (6 am–10 am)	-23.816328	150.550781	25
3/03/2020	Morning (6 am–10 am)	-23.81638452	150.550749	2

Date	Survey Period	Latitude (GDA94)	Longitude (GDA 94)	Count
3/03/2020	Morning (6 am–10 am)	-23.81248477	150.5196786	1
4/03/2020	Morning (6 am–10 am)	-23.816097	150.551132	16
4/03/2020	Morning (6 am–10 am)	-23.826971	150.543045	10
4/03/2020	Morning (6 am–10 am)	-23.811903	150.519531	7
4/03/2020	Morning (6 am–10 am)	-23.816105	150.551132	1
4/03/2020	Morning (6 am–10 am)	-23.816105	150.551147	6
4/03/2020	Morning (6 am–10 am)	-23.821007	150.549469	4
12/11/2020	Midday (6 am–10 am)	-27.7006771	152.9148582	4
23/01/2021	Morning (6 am–10 am)	-23.91164328	150.5654752	180
23/01/2021	Morning (6 am–10 am)	-23.91502085	150.567564	45
29/02/2020	Midday (10 am–2 pm)	-23.866512	150.6091	15
4/03/2020	Midday (10 am–2 pm)	-23.886278	150.617828	25
4/03/2020	Midday (10 am–2 pm)	-23.886259	150.617813	25
4/03/2020	Midday (10 am–2 pm)	-23.899616	150.623108	4
4/03/2020	Midday (10 am–2 pm)	-23.891569	150.618912	5
8/11/2020	Midday (10 am–2 pm)	-23.8726454	150.5926574	5
23/01/2021	Midday (10 am–2 pm)	-23.91468987	150.6024838	120
11/11/2020	Midday (10 am–2 pm)	-23.82534656	150.5420071	10
22/1/2021	Midday (10 am–2 pm)	-23.91879832	150.5908907	20
22/1/2021	Midday (10 am–2 pm)	-23.9152745	150.5684851	3
14/02/2020	Afternoon (2 pm–6 pm)	-23.79161437	150.5870644	5
25/02/2020	Afternoon (2 pm–6 pm)	-23.862768	150.562439	43
8/11/2020	Afternoon (2 pm–6 pm)	-23.873354	150.5921572	1

While only nine of these records were made during the bird utilisation survey, minimum and maximum flight height was often recorded during other ecological surveys, allowing for analysis of 76.7% of all records (**Graph 3.6**). Needletails were observed transiting through and foraging in circular movements through the Study Area airspace. Approximately 50% of observations involved flocks of 10 or more individuals, with two large flocks of 120 and 180 needletails recorded during an ecological survey in January 2021. A total of 73.3% of observations involved flight within the RSA.

Records throughout a migration event generally began during spring when the species arrives in Australia and ended in autumn when the species is leaving Australia. Data has been collected across two migration events recording 310 individuals during the 2019-2020 migration and 384 individuals during the 2020–2021 migration.



Graph 3.6 **White-throated needletail minimum and maximum heights**

3.2.3 Bat Utilisation Survey

Call data from the anabat swift units from all bat utilisation surveys found 18 microbats to be present in the Study Area, nine of which were found during every season surveyed (**Table 3.6**). None of the microbat species identified are listed under the EPBC Act or NC Act. Total calls from each species and mixed groups are presented in **Appendix C**.

Table 3.6 **Microbat species detected during all call detection nights**

Common Name	Scientific Name	Jul 2019	Feb-Mar 2020	Nov 2020	Jan 2021	Feb 2022
bristle-faced free-tailed bat	*Setirostris eleryi*		X			
chocolate wattled bat	*Chalinolobus morio*	X	X	X	X	X
eastern bent-winged bat	*Miniopterus orianae*	X	X	X	X	
eastern free-tailed bat	*Ozimops ridei*	X	X	X	X	X
eastern horseshoe-bat	*Rhinolophus megaphyllus*	X	X		X	X
Gould's wattled bat	*Chalinolobus gouldii*	X	X	X	X	X
hoary wattled bat	*Chalinolobus nigrogriseus*		X	X	X	X
inland broad-nosed bat	*Scotorepens balstoni*		X			X
lesser long-eared bat or Gould's long-eared bat	*Nyctophilus sp (N. geoffroyi or N. gouldi)*		X			X
little bent-wing bat	*Miniopterus australis*	X	X	X	X	X
little broad-nosed bat	*Scotorepens greyii*	X	X	X	X	X

Common Name	Scientific Name	Jul 2019	Feb-Mar 2020	Nov 2020	Jan 2021	Feb 2022
little pied bat	*Chalinolobus picatus*		X			X
northern broad-nosed bat	*Scotorepens sanborni*	X	X	X	X	X
northern freetail bat	*Chaerephon jobensis*	X	X	X	X	X
northern free-tailed bat	*Ozimops lumsdenae*	X	X	X	X	X
south-eastern broad-nosed bat	*Scotorepens orion*				X	X
Troughton's sheathtail bat	*Taphozous troughtoni*		X			X
yellow-bellied sheathtail bat	*Saccolaimus flaviventris*	X	X		X	X

3.3 Likelihood of Occurrence

The likelihood of occurrence assessment includes the five recorded listed species, and an additional five species with a High or Moderate potential of occurring in the Study Area (**Table 3.7**).

Table 3.7 Likelihood of Occurrence

Common Name	Scientific Name	NC Act Status	EPBC Act Status
Known			
glossy black-cockatoo	*Calyptorhynchus lathami erebus*	Vulnerable	-
rufous fantail	*Rhipidura rufifrons*	Special Least Concern	Migratory
spectacled monarch	*Monarcha trivirgatus*	Special Least Concern	Migratory
squatter pigeon (southern)	*Geophaps scripta scripta*	Vulnerable	Vulnerable
white-throated needletail	*Hirundapus caudacutus*	Vulnerable	Vulnerable; Migratory
High			
black-faced monarch	*Monarcha melanopsis*	Special Least Concern	Migratory
oriental cuckoo	*Cuculus optatus*	Special Least Concern	Migratory
fork-tailed swift	*Apus pacificus*	Special Least Concern	Migratory
satin flycatcher	*Myiagra cyanoleuca*	Special Least Concern	Migratory
Moderate			
Latham's snipe	*Gallinago hardwickii*	Special Least Concern	Migratory

3.4 Risk Assessment

Based on the risk rating criteria outlined in **Section 2.4.2** and **Section 2.4.3**, 35 bird species and 21 bat species were included in the risk assessment. The risk rating for each bird and bat species considered in the risk assessment is presented in **Table 3.8**.

An additional three species have been assessed despite their low likelihood of occurrence within the Study Area including red goshawk, ghost bat and grey-headed flying fox. The inclusion of these species in the risk assessment is resultant of the Project's Request for Information (RFI) as requested by DCCEEW. These species have been addressed in **Section 3.4.1**, **Section 3.4.2** and **Section 3.4.3**.

The rationale for species ranked Very High and Moderate-High is also listed in this section, and the remaining species' risks are discussed in **Appendix D**.

Table 3.8 Risk Assessment Ratings

Common Name	Scientific Name	Likelihood	Consequence	Risk Rating
white-throated needletail	*Hirundapus caudacutus*	High	High	**Very High**
microbat species	*microchiroptera*	High	Low-Moderate	**Moderate-High**
red goshawk	*Erythrotriorchis radiatus*	Low	High	**Moderate**
ghost bat	*Macroderma gigas*	Low	High	**Moderate**
grey-headed flying-fox	*Pteropus poliocephalus*	Moderate	Moderate	**Moderate**
Australian magpie	*Gymnorhina tibicen*	High	Low	**Moderate**
black flying fox	*Pteropus alecto*	High	Low	**Moderate**
black kite	*Milvus migrans*	High	Low	**Moderate**
brown falcon	*Falco berigora*	High	Low	**Moderate**
brown goshawk	*Accipiter fasciatus*	High	Low	**Moderate**
channel-billed cuckoo	*Scythrops novaehollandiae*	High	Low	**Moderate**
collared sparrowhawk	*Accipiter cirrocephalus*	Moderate	Moderate	**Moderate**
glossy black-cockatoo	*Calyptorhynchus lathami*	Moderate	Moderate	**Moderate**
grey goshawk	*Accipiter novaehollandiae*	Moderate	Moderate	**Moderate**
nankeen kestrel	*Falco cenchroides*	High	Low	**Moderate**
noisy friarbird	*Philemon corniculatus*	High	Low	**Moderate**
peregrine falcon	*Falco peregrinus*	High	Low	**Moderate**
pacific baza	*Aviceda subcristata*	High	Low	**Moderate**
fork-tailed swift	*Apus pacificus*	High	Low	**Moderate**
pied currawong	*Strepera graculina*	High	Low	**Moderate**
rainbow bee-eater	*Merops ornatus*	High	Low	**Moderate**
squatter pigeon	*Geophaps scripta scripta*	Moderate	Moderate	**Moderate**
topknot pigeon	*Lopholaimus antarcticus*	High	Low	**Moderate**
Torresian crow	*Corvus orru*	High	Low	**Moderate**
tree martin	*Petrochelidon nigricans*	High	Low	**Moderate**
wedge-tailed eagle	*Aquila audax*	High	Low	**Moderate**
whistling kite	*Haliastur sphenurus*	High	Low	**Moderate**

Common Name	Scientific Name	Likelihood	Consequence	Risk Rating
black-faced monarch	*Monarcha melanopsis*	Moderate	Low	**Minor**
blue-faced honeyeater	*Entomyzon cyanotis*	Moderate	Low	**Minor**
galah	*Eolophus roseicapilla*	Moderate	Low	**Minor**
Latham's snipe	*Gallinago hardwickii*	Moderate	Low	**Minor**
oriental cuckoo	*Cuculus optatus*	Moderate	Low	**Minor**
rainbow lorikeet	*Trichoglossus moluccanus*	Moderate	Low	**Minor**
red-tailed black-cockatoo	*Calyptorhynchus banksii*	Moderate	Low	**Minor**
rufous fantail	*Rhipidura rufifrons*	Moderate	Low	**Minor**
satin flycatcher	*Myiagra cyanoleuca*	Moderate	Low	**Minor**
spectacled monarch	*Symposiachrus trivirgatus*	Moderate	Low	**Minor**
scaly-breasted lorikeet	*Trichoglossus chlorolepidotus*	Moderate	Low	**Minor**
sulphur-crested cockatoo	*Cacatua galerita*	Moderate	Low	**Minor**

3.4.1 Red Goshawk

3.4.1.1 Information on red goshawk from Australian wind farms

There is no publicly available information on blade strike from wind farms located within this species' Australian range. Raptors and other large birds of prey are particularly susceptible to collision risk at wind farms. The placement of wind turbines coincides with areas where raptors soar on ridge-lift (Debus 2019).

3.4.1.2 Likelihood and Consequence of Impacts

The overall risk rating for red goshawk is Moderate, based on a Low likelihood and High consequence of collisions. The rationale for responses to each criterion is as follows:

- Red goshawk was not recorded during Project associated surveys as such, it is difficult to determine whether red goshawk flight activity occurs at RSA height. One study indicated the species is capable of flying up to 150 m AGL (Hertog 1986). Another study describing behaviour of what was potentially a pair of red goshawks described the species flying approximately 25–30 m above tree height (Smith 1991). Given the lack of flight data and observations of the species during Project associated surveys it can be assumed based on the above information that a portion of red goshawk flight activity could occur at RSA height.

- Despite extensive survey through bird utilisation surveys over four seasons and diurnal bird survey throughout the field survey program, red goshawk was not recorded within the Study Area. The species is considered to be extinct in the Rockhampton region (Noske 2021).

- Red goshawk is sparsely disbursed across coastal and sub-coastal regions of northern and eastern Australia from the Kimberley Division to north-eastern New South Wales (Marchant & Higgins 1993). The species and its habitat are widely distributed.

- The life-history characteristic of red goshawk overlap with certain aspects of both the descriptions for a 'low' and 'high' rating for Criterion D (Marchant & Higgins 1993).
- The total red goshawk Australian population is estimated to be 900 to 1400 mature individuals (BirdLife International 2022).
- The listing status of red goshawk is Vulnerable under the EPBC Act and Endangered under the NC Act.

The red goshawk's risk rating of Moderate reflects the low likelihood of collision in the Study Area if the species were to occur and the potentially high consequence. This assessment has been made based on assumptions relevant to red goshawk flight heights and the associated risk of collision if the species were to occur within the Study Area. The likelihood of occurrence assessment has identified red goshawk as having a low likelihood of occurring within the Study Area.

Table 3.9 Red goshawk risk assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low		X	X			
Moderate				X		
High	X				X	X
Risk Rating						
Likelihood	Low	**Consequence**	High	**Risk Rating**	Moderate	

3.4.2 Ghost Bat

3.4.2.1 Information on ghost bat from Australian wind farms

There is no publicly available information on blade strike from the majority of wind farms located in this species' Australian range.

3.4.2.2 Likelihood and Consequence of Impacts

The overall risk rating for ghost bat is Moderate, based on a Low likelihood and High consequence of collisions. The rationale for responses to each criterion is as follows:

- Ghost bat was not recorded during Project associated surveys however, it is unlikely to regularly fly at RSA height.
- Ghost bat was not recorded during project associated surveys. Database records (ALA 2022b) indicate the species has the potential to occur within the general location of the Study Area indicating a moderate likelihood of occurrence based on an anticipated low presence within the Study Area.
- Ghost bat distribution is largely discontinuous, and species aggregate and rely on caves (Threatened Species Scientific Committee (TSSC) 2016).
- The life-history characteristic of ghost bat overlap with certain aspects of both the descriptions for a 'low' and 'high' rating for Criterion D (TSSC 2016).

- The total population of ghost bat is estimated at between 4,000 and 6,000 individuals (Armstrong *et al.* 2021).

- The listing status of ghost bat is listed as Vulnerable under the EPBC Act and Endangered under the NC Act.

Ghost bat's Moderate risk rating largely reflects the high consequence of blade strike and low likelihood of collision in the Study Area is likely to have on this species overall.

Table 3.10 Ghost Bat Risk Assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low	X	X				
Moderate				X	X	
High			X			X
Risk Rating						
Likelihood	Low	**Consequence**	High	**Risk Rating**	Moderate	

3.4.3 Grey-headed Flying-Fox

3.4.3.1 Information on ghost bat from Australian wind farms

There is no publicly available information on blade strike from the majority of wind farms located in this species' Australian range.

3.4.3.2 Likelihood and Consequence of Impacts

The overall risk rating for grey-headed flying-fox is Moderate, based on a Moderate likelihood of collision and Moderate consequence of collisions. The rationale for responses to each criterion is as follows:

- Grey-headed flying-fox was not recorded during Project associated surveys. They regularly fly below RSA height and are capable of flying at RSA height.

- Grey-headed flying-fox was not recorded during project associated surveys. Database records indicate the species irregularly occurs in low numbers in the region and the nearest camps where occupation has been observed are at the maximum nightly foraging extent of the species. As such this species has been assessed as having a low likelihood of occurrence.

- Grey-headed flying-fox is nomadic and widely dispersed within areas of suitable habitat, and the habitat itself is widely dispersed.

- The life-history characteristic of grey-headed flying fox overlap with certain aspects of both the descriptions for a 'low' and 'high' rating for Criterion D.

- The total population of grey-headed flying-fox is estimated at 25,000 individuals.

- The listing status of grey-headed flying-fox is Vulnerable under the EPBC Act and the NC Act.

Table 3.11 Grey-headed Flying-fox Risk Assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low		X			X	
Moderate	X		X	X		X
High						
Risk Rating						
Likelihood	Moderate	**Consequence**	Moderate	**Risk Rating**	Moderate	

3.4.4 White-throated Needletail

3.4.4.1 Information on white-throated needletail from Australian wind farms

White-throated needletail has been assigned an overall risk rating of Very High. This species is particularly vulnerable to blade strike (Hull *et al.* 2013). Five birds have been found during post-construction mortality monitoring conducted at 15 wind farms in Victoria from 2003 to 2018 (Moloney, Lumsden & Smales 2019). There are 11 records of blade strike of white-throated needletail at both Bluff Point Wind Farm and at Studland Bay Wind Farm in north-west Tasmania (Hull *et al.* 2013). White-throated needletail are known to have collided with wind turbines in south-east New South Wales, with much of the data collected in this region being not publicly available (BCD unpublished data). Despite this, there are six records of deceased white-throated needletail at Capital Wind Farm from 2012/13 on the Atlas of Living Australia.

3.4.4.2 Likelihood and Consequence of Impacts

The overall risk rating for white-throated needletail is Very High, based on a High likelihood and High consequence of collisions. The rationale for responses to each criterion is as follows:

- A high proportion of the white-throated needletail's flight activity is at RSA height.
- White-throated needletail regularly occurs in or moves through the Study Area between October and April.
- An ecologically significant proportion of the white-throated needletail's population is likely to occur in and migrate through the Study Area each year due to the Study Area's location and position in the landscape spanning the forested eastern escarpment of the Great Dividing Range. Observations from the Study Area indicate that an internationally significant proportion of its population occurs in the Study Area annually (Department of the Environment 2015). The Study Area spans the main north – south corridor of forested mountainous habitat in the greater region and is hence likely to comprise important foraging and roosting habitat and constitute the most frequently used migratory pathway in the region. Hence, criterion C is assigned 'high'.
- The life-history characteristics of the white-throated needletail overlap with certain aspects of both the descriptions for a 'low' and 'high' rating for Criterion D (Higgins 1999).
- The total population for the species is estimated to be approximately 41,000 birds (Garnett and Baker 2021) and has undergone a 30 to 50% decline in recent decades (Tarburton 2014; TSSC 2019).
- White-throated needletail is listed as Vulnerable and migratory under the EPBC Act.

The white-throated needletail's risk rating of Very High reflects the high likelihood of collision in the Study Area and the potentially high consequence of such given a substantial proportion of the white-throated needletail's declining population is likely to occur in and move through the Study Area each year.

Table 3.12 White-throated Needletail Risk Assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low						
Moderate				X	X	X
High	X	X	X			
Risk Rating						
Likelihood	High	**Consequence**	High	**Risk Rating**	Very High	

3.4.4.3 Collision Risk Modelling

Species that received a Very High overall risk rating from the risk assessment in **Section 3.4** were subject to collision risk modelling to determine the actual predicted impacts to the species from the Project.

Collision risk modelling was provided by Biosis for white-throated needletail for the Mount Hopeful Wind Farm based on the BBUS data that has been collected for the Project (**Section 2.4;** Appendix B of Attachment G (Bird and Bat Adaptive Management Plan) of the Preliminary Documentation).
The assessment was based on the two different turbine dimensions outlined in **Section 1.2.2**. The results are presented as the projected annual number of potential collisions and are presented in **Table 3.13**.

Table 3.13 Annual Collision Risk Model Results for White-throated Needletail

Turbine Option	Estimated Annual Number of Collisions for Three Dynamic Avoidance Rate Scenarios		
	0.990	0.995	0.999
Turbine A	0.172	0.089	0.022
Turbine B	0.166	0.083	0.017

At the time of writing this report no empirical data was available to determine the avoidance capacity of white-throated needletails at wind energy facilities. Given the agility of the species it is probable that their capacity to avoid collisions is within the range of modelled avoidance rates set out in **Table 3.13**. At a lower, conservative extreme, the results at 0.99 dynamic avoidance rate are about 0.17 collisions per annum for white-throated needletails for either of the two turbine specifications modelled. This would equate to an approximate average of one white-throated needletail collision in 5.9 years. Results for the highest avoidance rate of 0.999 (estimated annual collision of approximately 0.02) would equate to an approximate average of one white-throated needletail collision in 50 years.

Results of the collision risk modelling undertaken by Biosis (Appendix B of Attachment G of the Preliminary Documentation) indicate little difference in risk to white-throated needletails between the two turbine options. As noted above, the differences in flight heights below and within RSA as they relate to the two turbine specifications are due to a single observation of 29 birds recorded at 70 metres height. Thus, the small difference between modelled results cannot be considered to be a reliable indicator of different risks due to the different rotor heights of the two turbines.

Rather than rotor-height, the primary factor influencing the slightly different results for the two turbines is the higher rotor speed of Turbine A, with an average of 12.1 revolutions per minute, compared to an average rotor speed of 9.7 revolutions per minute for Turbine B. As the average flight speed of the species is held as a constant in the risk model, greater rotor speed exposes a bird interacting with a turbine to a heightened level of collision risk.

3.4.5 Non-listed Microbats

A total of 18 non-listed microbats were detected in the Study Area during bat call detection nights, with four species recorded from the Anabat Swift device placed at 50 m AGL (Gould’s wattled bat, little bent-wing bat, northern freetail bat, yellow-bellied sheathtail bat), noting that calls may be detected from approximately 20 m below the device.

Of the species detected in the Study Area it is considered probable that seven species may fly above 55 to 80 m AGL, namely Gould's wattled bat, large bent-winged bat, northern freetail bat, northern free-tailed bat, eastern free-tailed bat, yellow-bellied sheathtail bat, Troughton's sheathtail bat. In the absence of data from RSA height in the Study Area a very high level of uncertainty is inherently associated with any estimate relating to whether each species rarely, occasionally or regularly flies at RSA height (a crucial component of the risk assessment method followed in this report).

Given the height of the RSA proposed to be installed in the Study Area it is unlikely that any of these species match a High rating for Criterion A, that is a species in which a high proportion of flight activity is at RSA height. Rather a Moderate rating is most accurate for the seven aforementioned species identified as being most likely to fly at RSA height. Thus, either an overall risk rating of Moderate may be most accurate for those of the aforementioned seven species that are assigned an overall Low rating for consequence and an overall risk rating of High for species assigned an overall Moderate rating for consequence.

Table 3.14 Microbat Risk Assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low			X		X	X
Moderate	X			X	X	
High		X				
Risk Rating						

Likelihood	High	**Consequence**	Low - Moderate	**Risk Rating**	Moderate - High

4.0 Potential Impacts

This section provides a high-level overview of common impacts to volant wildlife from wind turbine projects. A final BBAMP that addresses these impacts along with site-specific and regional considerations of wind farm-species interactions will be prepared prior to the operation of the wind farm.

Additionally, Appendix E of Attachment B (Assessment of Matters of National Environmental Significance) of the Preliminary Documentation includes a significant impact assessment, which considers impacts to threatened species based on the area of relevant habitat to be impacted by the Project.

4.1 Collisions

Mortality at wind farms can result from birds or bats colliding with wind turbine blades, towers, nacelles, guy cable, power lines and meteorological masts. There are a range of factors that influence risk of collisions with such infrastructure including (Drewitt & Langston 2008):

- Physical attributes of a wind turbine generator (i.e., turbine dimensions, lighting).
- Species-specific variables (i.e., abundance, flight behaviour, turbine avoidance capacity).
- Biophysical attributes (i.e., landscape position, topography, vegetation type).

Factors falling under the latter two points are often interrelated and generally highly spatially and temporally variable by nature. Proximity to roost locations, migratory flight pathways and wetlands appear to be particularly important factors that influence bird and bat utilisation. A range of other factors not necessarily related to a site's biophysical state such as weather conditions (inc. wind speed, temperature and relative humidity) can also affect utilisation and therefore collision risk (e.g., Amorim 2012).

Data from Australia, Europe and North America indicate that the risk of collision is likely to be highest in any given area or landscape where species most susceptible to collision (i.e., migratory species, raptors, swifts, waterbirds, high flying microbats) most frequently occur and lowest in areas where activity of such species is comparatively low. The consequence of mortality resulting from collision for any given species is largely influenced by the species' population size and life history traits such as longevity and fecundity which combine to determine a species' capacity to replace individuals lost.

4.2 Barotrauma

Barotrauma is a phenomenon in which rapid air pressure changes cause tissue damage to air-containing structures, most notably the lungs (Baerwald *et al.* 2009). It is thought that barotrauma can also result in non-lethal injuries, such as hearing impairments and other internal injuries that may result in bats succumbing to their injuries away from turbines (US Fish and Wildlife Service 2012).

Research conducted in North America on the relative risk of barotrauma compared with direct collisions has resulted in mixed findings regarding the proportion of deaths that have been attributed to each factor (Ellison 2012) though it appears the majority of fatalities are due to collisions (Grodsky *et al.* 2011; Rollins *et al.* 2012).Baerwald *et al.* (2009) found that barotrauma to the lungs and possibly other organs accounted for 46% of bats killed at turbines with 92% of bats having haemorrhaging in the thoracic and/or abdominal cavities. Rollins *et al.* (2012) found that only 6% (5/81) of bats collected at a wind farm in Illinois had lesions possibly consistent with barotrauma etiology leading the authors to conclude that 'traumatic injury is the major cause of bat mortality at wind farms, and, at best, barotrauma is a minor etiology'.

Due to the difficulty in diagnosing barotrauma unless the carcass is examined immediately after death, it is possible that cases attributed to barotrauma have been confused with traumatic injury associated with direct collisions.

There is currently no published information on barotrauma in Australia.

4.3 Barrier Effects

Barrier effects can be caused by wind turbines disrupting links between feeding, roosting and/or nesting areas, or diverting flights, including migratory flights, around a wind farm (Hötker, Thomsen & Köster 2006; Schuster, Bulling & Köppel 2015). Migrating species that pass wind farms frequently such as swifts appear to be of higher concern than other species (Hötker, Thomsen & Köster 2006). However, these effects on birds, possibly resulting in higher energy consumption or injuries as a result of collision, are not yet well known (Schuster, Bulling & Köppel 2015).

There is currently no published information on barrier effects from wind farms in Australia.

5.0 Management Actions

Neoen propose an adaptive management approach to turbine strike impacts, informed by seasonal surveys. This section outlines the adaptive management approach and presents mitigation measures which are considered in the Preliminary Bird and Bat Adaptive Management Plan (BBAMP) (Attachment G of the Preliminary Documentation).

5.1 Adaptive Management Plan

Neoen will undertake monitoring and management actions in accordance with the BBAMP for the Project (Attachment G of the Preliminary Documentation). The strategy of the management plan is to monitor and mitigate the potential impacts of turbine strike on birds and bats via trigger based, adaptive management. Pre and post commissioning monitoring of bird and bat activity (including flight behaviours) is a key requirement of the plan. The monitoring will inform a risk profile of each turbine to direct tailored management actions as when, and where required.

The specific objectives of the BBAMP include:

- Provide an overview of pre-commissioning survey results for the Project.
- Present the outcomes of the collision risk assessment, focussing on species which were deemed a high or very high risk of collision impacts.
- Present an overview of post-commissioning survey requirements including further bird and bat utilisation survey, as well as a carcass detection program.
- Provide proposed impact trigger thresholds for EPBC Act listed threatened and migratory species.
- Present the adaptive management framework to be initiated in the event that a trigger threshold is reached or exceeded.
- Outline ongoing and preventative mitigation and management measures, as well as reporting requirements.

5.2 Mitigation Measures

There are a range of mitigation measures employed at wind farms globally to reduce the impact of operating turbines on birds and bats. These include measures designed to deter birds and bats from turbines, measures employed to minimise the attractiveness of turbines and measures used to lure birds and bats away from turbines. Other measures include altering the operation of turbines such that the risk of birds and/or bats that do fly through a turbine's RSA may be at lower risk of impact. Despite the widespread implementation of several mitigation measures there has been relatively little empirical research conducted on the efficacy of the majority of those that have been employed (Gartman *et al.* 2016). Only a few mitigation measures specifically employed to reduce bird and bat collision risk overseas are regularly implemented in Australia and to date there has been no empirical research published on the effectiveness of mitigation measures employed here.

This section outlines the main mitigation measures that have been employed in Australia and/or overseas with a focus on cases where measures appear to be effective in reducing direct impacts, noting that the aforementioned BBAMP will provide a more detailed plan for adaptive management actions to reduce impacts.

5.2.1 Carrion Removal

Removal of carrion from near turbines is undertaken at wind farms (particularly in Australia) to mitigate the risk of carrion feeders such as raptors and other scavengers colliding with turbines. Carrion removal programs typically involve regular searches of target areas for any animal. Regular searches and removal limit the amount of time carcasses are present to attract scavengers and can be complemented by opportunistic identification by personnel undertaking unrelated work at a given wind farm.

Despite carrion removal programs being a key component of most bird and bat adaptive management plans prepared for wind farms in Australia, there is currently no publicly available information based on empirical research on their effectiveness. However, regular carrion removal is an established technique to reduce the presence of aerial scavengers employed in aviation to reduce the risk of aircraft bird strike (Australian Airports Association 2016).

5.2.2 Lighting

There is inconsistency amongst recommended use of (or avoidance of) lighting on wind turbines to specifically reduce impacts on birds and bats. This is probably partly due to variability in the way in which different species appear to respond (or not) to different lighting arrangements or configurations (i.e., according to colour, constant vs flashing etc) and the overall poor understanding of bird and bat interactions with turbines at night.

In instances where lighting is required on wind turbines it appears that the use of synchronised, flashing red lights is the best option for mitigating bird and bat collisions at night. There are evidence that steady-burning lights on communication towers increase the risk of collision for nocturnal migrants (Longcore, Rich & Gauthreaux 2008). Gehring, Kerlinger & Manville (2009) found that communication towers with red strobe, red flashing, and white strobe lights result in less mortality than towers with steady-burning lights. The use of synchronised, flashing red aviation lights on wind turbines was recommended by Kerlinger *et al.* (2010) to mitigate risk of blade strike for birds as it was found that their use does not attract birds. A study conducted by Bennett & Hale (2014) found that use of flashing red aviation lights does not appear to be one of the potential causes of bat fatalities at wind farms leading the authors to recommend red aviation lights on turbines over other options to manage impacts on bats.

There is currently no information on the influence of lighting on wind turbines on bird and bat collision risk in Australia.

5.2.3 Painting Turbines

May *et al.* (2020) demonstrated that painting one wind turbine blade black reduced the annual bird fatalities across a range of bird species by 70%, compared to a non-painted turbine. Painting a turbine blade increased rotor visibility by reducing 'motion smear', the phenomenon where fast-moving objects appear to blend together.

It is noted that painting turbine blades would conflict with standard conditions of wind farm project approval, and this measure would require additional authorisation from regulators and special consideration from all stakeholders.

5.2.4 Temporary Shutdown Periods

Employing temporary shutdown of turbines has been shown to be an effective measure for reducing fatalities of certain birds and bats (de Lucas et al. 2012; Gartman et al. 2016; Smallwood & Bell 2020). For example, de Lucas et al. (2012) investigated mortality rates for Griffon vulture (*Gyps fulvus*) at 10 out of 13 wind facilities in Spain by conducting turbine shutdown programs from 2008 to 2009 and compared rates from a non-stop program in 2006 to 2007. The researchers found that selectively stopping a few turbines during a few months of the year can significantly reduce mortality rates by more than 50% (de Lucas *et al.* 2012; Gallego *et al.* 2011). This mortality reduction was achieved through short shutdown periods between the first two hours after sunrise until the last two hours before sunset, resulting in only a negligible reduction (0.07%) in energy production (de Lucas et al. 2012). In another study, Smallwood & Bell (2020) found that employing turbine shutdown periods significantly reduced fatalities of bats but not of birds in the United States.

Temporary turbine shutdowns specifically designed to reduce the risk of strike of a threatened bird species (Tasmanian wedge-tailed eagle (*Aquila audax fleayi*)) are employed at the Cattle Hill Wind Farm in Tasmania, however the effectiveness of this measure on reducing collision risk has not been reported.

5.2.5 Altering Cut-In Speed of Turbines (Curtailment)

Increasing the cut-in speed of wind turbines (the velocity at which turbines start producing electricity) appears to be the most effective mitigation measure for reducing microbat mortality partly because bat mortality rates are generally higher during nights with low wind speeds (Kerns, Erickson & Arnett 2005; Rydell et al. 2010; Amorim, Rebelo & Rodrigues 2012). Investigations conducted in North America indicate that bat mortality can be reduced by increasing the cut-in speed with reductions from 30% to 90% being reported (Arnett et al. 2008; Baerwald et al. 2009; Arnett et al. 2010). Similarly, Wellig *et al.* (2018) found that collision risk could be drastically reduced if nocturnal operation of wind turbines would be restricted to wind speeds above 5 ms^{-1} at a site in Switzerland.

A curtailment study was undertaken at the Cape Nelson North wind farm in southwest Victoria which reported similar results to international studies showing a significant decrease in bat mortality of 54% when curtailment measures were applied to the site (Bennett *et al.* 2022). This mitigation measure appears to be most effective at locations where there is a high frequency of flights undertaken at RSA such as in migratory pathways.

6.0 Significant Impact Assessment

The potential for residual impacts on birds and bats as a result of wind turbine collisions, barotrauma and barrier effects was considered for significance against the Commonwealth Significant Impact Assessment (SIA) guidelines. Given the Project may also result in other impacts on fauna, such as habitat loss, SIAs were addressed in Attachment B of the Preliminary Documentation. A summary of this assessment, as it relates to this report are presented below.

The SIA assessment considered the potential impacts on threatened and migratory fauna, including threatened birds and bats identified as having a Moderate to Very High collision risk profile (**Section 3.4**). Disregarding habitat clearance impacts, the assessment identified no SIA to birds or bats as a result of turbine collision, barotrauma or barrier effects, noting the following reasons:

- Collision Risk Modelling:
  - Modelling for the white-throated needletail determined at a lower, conservative extreme, the results at 0.99 dynamic avoidance rate are 0.17 collisions per annum for white-throated needletails for either of the two turbine specifications modelled.
- Adaptive management:
  - The Project will be governed by a BBAMP, which identifies the operational response to bird and bat collisions in the event that mortalities are recorded and exceed trigger thresholds (the Preliminary BBAMP is provided as Attachment G of the Preliminary Documentation).
  - The BBAMP outlines a dynamic monitoring approach, with individual turbine risk profiles informing the frequency and timing of monitoring events, including carcass searches.
- Flight behaviours/infrequent visitation:
  - As documented in this report, numerous threatened and migratory species present a moderate collision due to the infrequency of flights at RSA or the infrequency of occurrence with the Study Area.
  - The predicted size of migratory bird populations, coupled with operational response measures as governed by the BBAMP reduce the likelihood of significant impacts on populations as a result of mortality from wind turbine collisions.
- Habitat availability/fauna movement corridors:
  - The Project is situated within and adjacent to a large, vegetated corridor associated with Ulam Range.
  - The Study Area does not support regionally unique habitat features (i.e., wetlands or other important foraging/roosting locations) that the Project would be otherwise restricting access to (e.g., flight barriers).
  - The Study Area does not support habitat features such as wetlands that may attract large groups of threatened or migratory water birds.
  - The Study Area does not support any known flying fox camps and is not positioned near mapped nationally important camp locations.

7.0 Conclusion

A total of 137 bird species were recorded within the Study Area during the field surveys; five of which are threatened and listed under state and/or federal legislation:

- Glossy black cockatoo.
- Rufous fantail.
- Spectacled monarch.
- Squatter pigeon (southern).
- White-throated needletail.

An additional four species were found to have a High likelihood of occurring in the Study Area, and one species with a Moderate likelihood of occurring.

The risk assessment found white-throated needletail to have a Very High risk of impact by the Project and for seven identified microbat species to have a Moderate to High-risk potential. An additional three species were included in the assessment based on the Project's RFI including red goshawk, grey-headed flying-fox and ghost bat. Despite these species Low likelihood of occurrence within the Study Area, they each received a Moderate overall risk rating. These species, along with other species with a Moderate and Minor risk potential, have been considered in the preliminary BBAMP.

In conjunction with the collision risk modelling undertaken by Biosis, the findings of this document have been used to develop the preliminary BBAMP which uses an adaptive management process to mitigate the risk of turbine strike and barotrauma on threatened and migratory bird and bat species listed under the EPBC Act. A Project BBAMP will be developed based on conditions of the Project approval which will seek to mitigate and manage Project risks on both EPBC Act and NC Act listed threatened species and non-threatened species. The preliminary BBAMP details mitigation and management procedures to be undertaken during the operational phase of the Project including:

- A carcass detection program as well as a detailed carcass persistence trial.
- A carrion removal program.
- The use of lighting and deterrents.
- Shutdown or curtailment processes based on unacceptable risks to white-throated needletail.
- Pre-clearance nest surveys for red goshawk.
- An adaptive management process based on the identification of unacceptable risks (trigger levels) to all threatened and migratory species.

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APPENDIX A

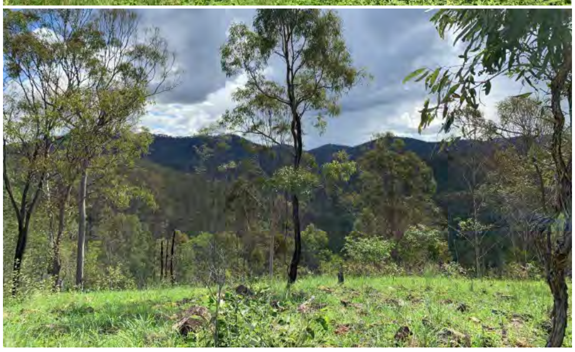
Vantage Point Photos

POM1



POM2





POM3

POM4

POM5

POM8



POM9

No photographs available.

NORTH1

No photographs available.

NORTH2


NORTH3

NORTH4

NORTH6


NORTH7




BC1




BC2

APPENDIX B

Survey Effort

Bird Utilisation Surveys

February–March 2020Vantage Point Survey Schedule (Autumn)

Survey Period	26 Feb	28 Feb	29 Feb	1 Mar	2 Mar	3 Mar	4 Mar
Morning (6:00–10:00)		POM2 POM3 POM9	POM3 POM5 POM8	POM3 POM4 POM9		NORTH1 NORTH4	NORTH2 NORTH3
Midday (10:00–14:00)	POM9	POM4	POM1 POM8	POM2 POM3	NORTH2 NORTH3	NORTH1 NORTH4	
Afternoon (14:00–18:00)	POM2	POM3	POM1 POM5	POM4 POM9	NORTH2 NORTH3	NORTH1 NORTH4	

November 2020 Vantage Point Survey Schedule (Spring)

Survey Period	5 Nov	6 Nov	7 Nov	8 Nov	9 NOV	10 Nov	11 Nov
Morning (6:00–10:00)	NORTH1 NORTH2 NORTH6 NORTH7	POM2 POM3 POM4 POM5	POM1 POM2 POM3 POM8	POM1 POM4 POM5 POM8	NORTH3 NORTH4	NORTH1 NORTH3 NORTH4 NORTH6	NORTH2 NORTH7
Midday (10:00–14:00)	NORTH1 NORTH3 NORTH4 NORTH6	POM1 POM3 POM4 POM8	POM2 POM4 POM5 POM8	POM1 POM2 POM3 POM5	NORTH2 NORTH6 NORTH7 POM1	NORTH2 NORTH3 NORTH4 NORTH7	
Afternoon (14:00–18:00)	NORTH2 NORTH3 NORTH4 NORTH7	POM1 POM3 POM4 POM5	POM1 POM3 POM4 POM5	POM2 POM3 POM8	NORTH1 NORTH3 NORTH4 NORTH6	NORTH2 NORTH6 NORTH7	

October 2021 Vantage Point Survey Schedule (Spring)

Survey Period	8 Oct	9 Oct	10 Oct	11 Oct	12 Oct	13 Oct	14 Oct	15 Oct
Morning (6:00–10:00)	NORTH7 NORTH8 NORTH6 NORTH4		NORTH6 NORTH4 NORTH7 NORTH8	POM1	POM4 POM8 POM3 POM1	POM5 POM4	BC1 BC2	POM3 POM8
Midday (10:00–14:00)	NORTH4 NORTH6 NORTH8 NORTH7	NORTH7 NORTH4 NORTH6 NORHT8		POM4 POM8 POM5 POM4	POM1 POM4 POM8 POM3	POM8 POM3 POM1 POM5	BC1 BC2	
Afternoon (14:00–18:00)	NORTH6 NORTH4 NORTH7 NORTH8	NORTH8 NORTH7 NORTH4 NORTH8		POM8 POM3	POM1 POM4	POM4 POM8 POM3 POM1	BC1 BC2	

February 2022 Vantage Point Survey Schedule (Summer)

Survey Period	14 Feb	15 Feb	16 Feb	17 Feb	18 Feb	19 Feb	20 Feb	21 Feb
Morning (6:00–10:00)		NORTH4 NORTH6			POM4 POM8	POM1 POM3 POM4 POM5	POM1 POM3 POM5 POM8	BC1 BC2 BC1 BC2
Midday (10:00–14:00)		NORTH4 NORTH6 NORTH7 NORTH8	NORTH4 NORTH6 NORTH7 NORTH8	NORTH4 NORTH7 NORTH8	POM1 POM3 POM4 POM5	POM3 POM4 POM5 POM8	POM1 POM3 POM4 POM8	BC1 BC2 BC1 BC2
Afternoon (14:00–18:00)	NORTH7 NORTH8	NORTH4 NORTH6 NORTH7 NORTH8	NORTH4 NORTH6	NORTH7	POM1 POM3 POM5 POM8	POM1 POM8	POM1 POM5	BC1 BC2

Bat Utilisation Surveys

July 2019 Survey Bat Call Detection Nights (Winter)

Site ID	Deployment Date	Retrieval Date	Total Nights
POM4	9/07/2019	11/07/2019	2
N/A (-23.8861, 150.5892)	9/07/2019	11/07/2019	2

February–March 2020 Survey Bat Call Detection Nights (Autumn)

Site ID	Deployment Date	Retrieval Date	Total Nights
North1	2/03/2020	4/03/2020	2
North2	2/03/2020	4/03/2020	2
North3	2/03/2020	4/03/2020	2
North4	2/03/2020	4/03/2020	2
POM1	25/02/2020	1/03/2020	5
POM2	25/02/2020	1/03/2020	5
POM3	29/02/2020	4/03/2020	4
POM4	26/02/2020	1/03/2020	4
POM5	26/02/2020	2/03/2020	5
POM8	1/03/2020	4/03/2020	3
POM9	26/02/2020	1/03/2020	4
Other (-23.92998, 150.57360)	26/02/2020	2/03/2020	5
Other (-23.89965, 150.62312	1/03/2020	4/03/2020	3

November 2020 Survey Bat Call Detection Nights (Spring)

Site ID	Deployment Date	Retrieval Date	Total Nights
North1	9/11/2020	11/11/2020	2
North2	9/11/2020	11/11/2020	2
North3	10/11/2020	12/11/2020	2
North4	9/11/2020	11/11/2020	2
North6	9/11/2020	11/11/2020	2
North7	9/11/2020	11/11/2020	2
Pom1	6/11/2020	7/11/2020	1
Pom2	6/11/2020	12/11/2020	6

Site ID	Deployment Date	Retrieval Date	Total Nights
Pom3	6/11/2020	9/11/2020	3
Pom4	6/11/2020	8/11/2020	2
Pom5	6/11/2020	8/11/2020	2
Pom8	6/11/2020	8/11/2020	2

January 2021 Survey Bat Call Detection Nights (Summer)

Site ID	Deployment Date	Retrieval Date	Total Nights
Other (-23.92635, 150.61061)	22/01/21	24/01/21	2
Other (-23.91968, 150.62659)	22/01/21	24/01/21	2

October 2021 Survey Bat Call Detection Nights (Spring)

Site ID	Deployment Date	Retrieval Date	Total Nights
North4	08/10/2021	10/10/2021	2
North6	08/10/2021	10/10/2021	2
North7	08/10/2021	10/10/2021	2
North8	08/10/2021	10/10/2021	2
POM1	11/10/2021	13/10/2021	2
POM3	11/10/2021	13/10/2021	2
POM4	11/10/2021	13/10/2021	2
POM5	11/10/2021	13/10/2021	2
POM8	11/10/2021	13/10/2021	2
Other (-23.7463,150.5279)	08/10/2021	10/10/2021	2
Other (-23.8649, 150.5582)	11/10/2021	13/10/2021	2

February 2022 Survey Bat Call Detection Nights (Summer)

Site ID	Deployment Date	Retrieval Date	Total Nights
North4	15/02/2022	17/02/2022	2
North6	15/02/2022	17/02/2022	2
North7	14/02/2022	17/02/2022	3
North8	14/02/2022	17/02/2022	3
POM1	18/02/2022	20/02/2022	2

Site ID	Deployment Date	Retrieval Date	Total Nights
POM3	18/02/2022	20/02/2022	2
POM4	18/02/2022	20/02/2022	2
POM5	18/02/2022	20/02/2022	2
POM8	18/02/2022	20/02/2022	2
Other (-23.8648, 150.5577)	18/02/2022	20/02/2022	2

APPENDIX C

Microbat Data

Microbat species and calls detected July 2019 (Winter)

Common Name	Scientific Name	Calls Detected
Individual Species		
eastern horseshoe-bat	*Rhinolophus megaphyllus*	188
northern freetail bat	*Chaerephon jobensis*	107
little bent-wing bat	*Miniopterus australis*	84
hoary wattled bat	*Chalinolobus nigrogriseus*	71
eastern free-tailed bat	*Ozimops ridei*	42
eastern bent-winged bat	*Miniopterus orianae*	5
northern free-tailed bat	*Ozimops lumsdenae*	4
northern broad-nosed bat	*Scotorepens sanborni*	3
chocolate wattled bat	*Chalinolobus morio*	2
Gould's wattled bat	*Chalinolobus gouldii*	2
little broad-nosed bat	*Scotorepens greyii*	1
Mixed Species Groups		
S. greyii / C. nigrogriseus		*8*

Microbat species and calls detected February – March 2020 (Autumn)

Common Name	Scientific Name	Calls Detected
Individual Species		
Gould's wattled bat	*Chalinolobus gouldii*	949
northern freetail bat	*Chaerephon jobensis*	844
northern free-tailed bat	*Ozimops lumsdenae*	327
northern broad-nosed bat	*Scotorepens sanborni*	298
yellow-bellied sheathtail bat	*Saccolaimus flaviventris*	264
little bent-wing bat	*Miniopterus australis*	209
eastern free-tailed bat	*Ozimops ridei*	187
large bent-winged bat	*Miniopterus orianae oceanensis*	160
chocolate wattled bat	*Chalinolobus morio*	62
long eared bat sp.	*Nyctophilus sp.(N. geoffroyi or N. gouldi)*	*45*
little broad-nosed bat	*Scotorepens greyii*	*30*
hoary wattled bat	*Chalinolobus nigrogriseus*	*20*

Common Name	Scientific Name	Calls Detected
inland broad-nosed bat	*Scotorepens balstoni*	*19*
eastern horseshoe-bat	*Rhinolophus megaphyllus*	*15*
Troughton's sheathtail bat	*Taphozous troughtoni*	*3*
bristle-faced free-tailed bat	*Setirostris* eleryi	1
Mixed Species Groups		
C. gouldii / S. balstoni / O. ridei		6051
C. jobensis / O. lumsdenae / S. flaviventris		1190
C. nigrogriseus / Scotorepens sp.		842
S. greyii / S. sanborni		653
S. greyii / S. sanborni / Chalinolobus picatus		63
M. o. oceanensis / S. sanborni		21
S. eleryi / S. greyii		6

Microbat species and calls detected November 2020 (Spring)

Common Name	Scientific Name	Calls Detected
Individual Species		
northern freetail bat	*Chaerephon jobensis*	2987
Gould's wattled bat	*Chalinolobus gouldii*	1661
eastern free-tailed bat	*Ozimops ridei*	397
northern broad-nosed bat	*Scotorepens sanborni*	382
little bent-wing bat	*Miniopterus australis*	355
little broad-nosed bat	*Scotorepens greyii*	65
hoary wattled bat	*Chalinolobus nigrogriseus*	21
yellow-bellied sheathtail bat	*Saccolaimus flaviventris*	20
eastern bent-wing bat	*Miniopterus orianae*	13
northern free-tailed bat	*Ozimops lumsdenae*	11
chocolate wattled bat	*Chalinolobus morio*	8
eastern horseshoe-bat	*Rhinolophus megaphyllus*	2
south-eastern broad-nosed bat	*Scotorepens orion*	1

Common Name	Scientific Name	Calls Detected
Mixed Species Groups		
C. gouldii / O. ridei		1196
S. greyii / C. nigrogriseus		95
S. sanborni / C. picatus		74
S. flaviventris / C. jobensis		3

Microbat species and calls detected January 2021 (Summer)

Common Name	Scientific Name	Calls Detected
Individual Species		
Gould's wattled bat	*Chalinolobus gouldii*	80
little broad-nosed bat	*Scotorepens greyii*	63
northern freetail bat	*Chaerephon jobensis*	20
northern broad-nosed bat	*Scotorepens sanborni*	11
eastern horseshoe-bat	*Rhinolophus megaphyllus*	8
yellow-bellied sheathtail bat	*Saccolaimus flaviventris*	6
eastern free-tailed bat	*Ozimops ridei*	4
little bent-wing bat	*Miniopterus australis*	2
eastern bent-wing bat	*Miniopterus orianae*	2
northern free-tailed bat	*Ozimops lumsdenae*	1
chocolate wattled bat	*Chalinolobus morio*	1
Mixed Species Groups		
S. sanborni / C. picatus		17
C. gouldii / O. ridei		10
S. greyii / C. nigrogriseus		2

Microbat species and calls detected October 2021 (Spring)

Common Name	Scientific Name	Calls Detected
Individual Species		
Gould's wattled bat	*Chalinolobus gouldii*	1272
hoary wattled bat	*Chalinolobus nigrogriseus*	146
little broad-nosed bat	*Scotorepens greyii*	976

Common Name	Scientific Name	Calls Detected
northern freetail bat	*Chaerephon jobensis*	365
northern broad-nosed bat	*Scotorepens sanborni*	248
eastern horseshoe-bat	*Rhinolophus megaphyllus*	4
yellow-bellied sheathtail bat	*Saccolaimus flaviventris*	164
eastern free-tailed bat	*Ozimops ridei*	4
little bent-wing bat	*Miniopterus australis*	308
eastern bent-wing bat	*Miniopterus orianae*	96
northern free-tailed bat	*Ozimops lumsdenae*	76
chocolate wattled bat	*Chalinolobus morio*	2
Mixed Species Groups		
C. gouldii / O. ridei		1882
C. nigrogriseus / S. greyii		765
S. greyii / S. sanborni		123
S. sanborni / Chalinolobus picatus		11

Microbat species and calls detected February 2022 (Summer)

Common Name	Scientific Name	Calls Detected
Individual Species		
Gould's wattled bat	*Chalinolobus gouldii*	*212*
northern freetail bat	*Chaerephon jobensis*	*380*
northern free-tailed bat	*Ozimops lumsdenae*	*37*
northern broad-nosed bat	*Scotorepens sanborni*	*39*
yellow-bellied sheathtail bat	*Saccolaimus flaviventris*	*46*
little bent-wing bat	*Miniopterus australis*	*79*
eastern free-tailed bat	*Ozimops ridei*	*15*
chocolate wattled bat	*Chalinolobus morio*	*1*
long eared bat sp.	*Nyctophilus sp.(N. geoffroyi or N. gouldi)*	*1*
little broad-nosed bat	*Scotorepens greyii*	*9*
hoary wattled bat	*Chalinolobus nigrogriseus*	*8*
inland broad-nosed bat	*Scotorepens balstoni*	*4*
eastern broad-nosed bat	*Scotorepens orion*	*2*

Common Name	Scientific Name	Calls Detected
eastern horseshoe-bat	*Rhinolophus megaphyllus*	*4*
Troughton's sheathtail bat	*Taphozous troughtoni*	*1*
little pied bat	*Chalinolobus picatus*	*38*
Mixed Species Groups		
C. gouldii / O. ridei		22
C. nigrogriseus / S. greyii		4
C. pictatus / S. sanborni		96

APPENDIX D

Risk Assessment

Risk Assessment

A total of 23 bird and eight bat species that met the criteria for inclusion in the risk assessment were assessed.

Non-listed bird and bat species (barring wedge-tailed eagle) were subject to a briefer risk assessment than species listed under the EPBC Act and/or the NC Act.

D.1 Threatened Birds

D1.1 Squatter pigeon

Information on squatter pigeon from Australian wind farms

There is no publicly available literature on blade strike at wind farms in the squatter pigeon's range.

Likelihood and Consequence of Impacts

The overall risk rating for squatter pigeon is Moderate, based on Moderate likelihood and Moderate consequence of collisions. The rationale for responses to each criterion is as follows:

- As the squatter pigeon is highly unlikely to fly at RSA height in the Study Area the overall rating for the likelihood of collision is deemed Low regardless of the response to criterion B.
- The squatter pigeon is a common resident in the Study Area.
- The southern subspecies of squatter pigeon (*Geophaps scripta scripta*) is widely dispersed within areas of suitable habitat and its habitat is relatively scattered.
- The life-history characteristics of the squatter pigeon match the description for a 'low' rating for Criterion D (Higgins and Davies 1996).
- Garnett & Crowley (2000) estimated the number of mature individuals to be approximately 40,000, although this estimate was considered to be of low reliability. The total squatter pigeon population is likely to exceed 20,000 however the southern subspecies' population may number between 5,000–20,000 individuals. Hence, criterion E is conservatively assigned Moderate.
- The southern subspecies of squatter pigeon is listed as vulnerable under the EPBC Act and the NC Act.

Squatter pigeon's Moderate ranking reflects the species' vulnerable listing and frequency of occurrence within the Study Area, despite the Low ranking for Criteria A, C and D.

Squatter Pigeon Risk Assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low	X		X	X		
Moderate					X	X
High		X				
Risk Rating						
Likelihood	Moderate	**Consequence**	Moderate	**Risk Rating**	Moderate	

D1.2 Glossy black-cockatoo

Information on glossy black-cockatoo from Australian wind farms

There are no publicly available information on blade strike from wind farms in the glossy black-cockatoo's range.

Likelihood and Consequence of Impacts

The overall risk rating for glossy black-cockatoo is Moderate, based on a Moderate likelihood and Moderate consequence of collisions. The rationale for responses to each criterion is as follows:

- Glossy black-cockatoo is an uncommon resident or visitor in the Study Area.
- Glossy black-cockatoo 's habitat is widely dispersed, and individuals do not typically congregate in large numbers in particular areas.
- The life-history characteristics of the glossy black-cockatoo overlap with certain aspects of both the descriptions for a 'low' and 'high' rating for Criterion D (Higgins 1999).
- Garnett and Crowley (2000) estimated the total population size of glossy black-cockatoo to comprise 17,140 individuals and the population occurring in the Study Area to comprise 5,000 individuals. Hence, criterion E is assigned 'moderate' based on total population size though it is noted that the population size may be less than 5,000.
- Glossy black-cockatoo is listed as vulnerable under the NC Act.

The glossy black-cockatoo's Moderate risk rating reflects the risk of collisions based on their presence in the Study Area and potential to fly at RSA height and the Moderate rating for consequence based on population size, their low reproduction rate and their status under the EPBC Act and the NC Act.

Glossy black-cockatoo risk assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low	X		X			
Moderate		X		X	X	X
High						
Risk Rating						

Likelihood	Moderate	**Consequence**	Moderate	**Risk Rating**	Moderate

D.2 Migratory Listed Birds

D2.1 Latham's snipe

Information on Latham's snipe from Australian wind farms

There are no records of blade strike of Latham's snipe in the available literature from Victoria (Moloney *et al.* 2019) or Tasmania (Hull *et al.* 2013). Latham's snipe was identified by Smales (2006) as being one of three of the highest priority species (in regard to collision risk) in the Gippsland region of Victoria based on risk posed by species' flight behaviour and conservations status.

Likelihood and Consequence of Impacts

The overall risk rating for Latham's snipe is Minor, based on a Moderate likelihood and Low consequence of collisions. The rationale for responses to each criterion is as follows:

- Latham's snipe regularly flies below RSA height and occasionally flies at RSA height though the height at which Latham's snipe tend to fly during migration is unknown.
- Latham's snipe is likely to be an infrequent visitor in the Study Area particularly during southward (July-September) and northward passage (February to April).
- Latham's snipe can congregate in relatively large numbers at certain wetland sites. Sites considered to support important habitat for Latham's snipe are those that regularly support at least 18 individuals (Department of the Environment 2015a). As no such sites are present in or near the Study Area, Criterion C is assigned 'low'.
- The life-history characteristics of the Latham's snipe overlap with certain aspects of both the descriptions for a 'low' and 'high' rating for Criterion D (Higgins and Davies 1996).
- Hansen *et al.* (2016) estimated that the total population of Latham's snipe which visits Australia is 30,000 individuals. Hence, criterion E is assigned 'low' though it is noted that recent population monitoring conducted in Hokkaido, Japan indicated a steep decline between 2018 (35,000 birds) to 2020 (20,000) (Wild Bird Society of Japan 2020).
- Latham's snipe is listed as migratory under the EPBC Act.

Latham's snipe was not recorded in the Study Area during the bird utilisation survey or incidentally during 2019/20. Latham's snipe may occasionally migrate through the Study Area during southward (July-September) or northward passage (February to April) (Higgins and Davies 1996). Dams in the Study Area comprise suitable stopover habitat though due to their limited habitat value (i.e., small size and lack of suitable vegetation cover) occurrences would be infrequent. No waterbodies in the Study Area constitute important habitat for Latham's snipe as per the important habitat guidelines for this species (Department of the Environment 2015a).

The Latham's snipe's Minor risk rating reflects the risk of blade strike of individuals migrating through the Study Area coupled with the minor consequence that the potential collision rate may have on their population.

Latham's snipe risk assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low			X		X	X
Moderate	X	X		X		
High						
Risk Rating						
Likelihood	Moderate	Consequence	Low	Risk Rating	Minor	

D2.2 Oriental cuckoo

Information on oriental cuckoo from Australian wind farms

There is no publicly available information on blade strike at wind farms within the oriental cuckoo's range in Australia.

Likelihood and Consequence of Impacts

The overall risk rating for oriental cuckoo is Minor, based on a Moderate likelihood and Low consequence of collisions. The rationale for responses to each criterion is as follows:

- Little is known about the height range in which oriental cuckoo fly whilst migrating, though the majority of movements are likely to occur below 55 m AGL.
- Oriental cuckoo is likely to regularly occur in or move through the Study Area between November – March.
- Though oriental cuckoo does not congregate in high numbers, a large proportion of the population that migrates south of the Study Area annually is likely to migrate through a relatively restricted area along the coast and eastern escarpment of the Great Dividing Range where the majority of suitable habitat is present. Hence, Criterion C is assigned Moderate.
- The life-history characteristics of oriental cuckoo matches the description for a Low rating for-Criterion D (Higgins 1999).
- The total population size has not been quantified though it is estimated to exceed 1 million (BirdLife International 2015).
- Oriental cuckoo is listed as migratory under the EPBC Act.

Oriental cuckoo are likely to regularly occur in or move through the Study Area between November to March but may be present as early as August (Higgins 1999). Oriental cuckoo typically arrive in Qld from their breeding grounds in the Northern Hemisphere during November/December and return north during February/March (Higgins 1999).

Oriental cuckoo's Minor overall risk rating reflects the anticipated regular occurrence within the Study Area, predicted low flight behaviour (below RSA) and minor rating for consequence based on their very large population size, capability to replace lost individuals and non-threatened status at the state and national scale.

Oriental cuckoo risk assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low	X			X	X	X
Moderate			X			
High		X				
Risk Rating						
Likelihood	Moderate	**Consequence**	Low	**Risk Rating**	Minor	

D2.3 Fork-tailed swift

Information on fork-tailed swift from Australian wind farms

There is one record of blade strike of fork-tailed swift in the available literature from Victoria (Moloney *et al.* 2019). There is no publicly available information on blade strike from the majority of wind farms located in this species' Australian range.

Likelihood and Consequence of Impacts

The overall risk rating for fork-tailed swift is Moderate, based on a High likelihood and Low consequence of collisions. The rationale for responses to each criterion is as follows:

- A high proportion of the fork-tailed swift's flight activity is at RSA height.
- Fork-tailed swift regularly occurs in or moves through the Study Area between October to April.
- Fork-tailed swift is widely dispersed throughout Australia and although it occasionally congregates in very high numbers it may do so anywhere in its range over a vast range of landforms and vegetation types.
- The life-history characteristics of fork-tailed swift overlap with certain aspects of both the descriptions for a 'low' and 'high' rating for Criterion D (Higgins 1999).
- The global population size has not been quantified, but the species is reported to be generally common throughout most of its breeding range (del Hoyo *et al.* 1999) and it is highly likely to exceed 20,000 individuals given national population estimates for China, Japan, Taiwan, South Korea and Russia (Birdlife Australia 2022).
- Fork-tailed swift is listed as migratory under the EPBC Act.

Fork-tailed swift are likely to regularly occur in or move through the Study Area between October to April in small to very large flocks (Higgins 1999).

Fork-tailed swift's Moderate risk rating largely reflects the relatively low consequence that blade strike in the Study Area is likely to have on this species overall.

Fork-tailed swift risk assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low			X		X	X
Moderate				X		
High	X	X				
Risk Rating						

Likelihood	High	Consequence	Low	Risk Rating	Moderate

D2.4 Rufous fantail

Information on rufous fantail from Australian wind farms

There are no records of blade strike of rufous fantail in the available literature from Victoria (Moloney *et al.* 2019) though there are only few records of rufous fantail in parts of western Victoria where post-construction monitoring has been conducted.

Likelihood and Consequence of Impacts

The overall risk rating for rufous fantail is Minor, based on a Moderate likelihood and Minor consequence of collisions. The rationale for responses to each criterion is as follows:

- Little is known about the height range in which rufous fantail fly whilst migrating though the majority of movements are likely to occur below 55 m AGL.
- Rufous fantail regularly occurs in or moves through the Study Area.
- Though the rufous fantail does not congregate in high numbers a large proportion of the population that migrates south of the Study Area annually is likely to migrate through a relatively restricted area along the coast and eastern escarpment of the Great Dividing Range where the majority of suitable habitat is present. Hence, Criterion C is assigned 'moderate'.
- The life-history characteristics of rufous fantail matches the description for a Low rating for Criterion D (Higgins et al. 2006).
- The total population of rufous fantail is estimated to exceed 20,000 individuals (Department of the Environment 2015b).
- Rufous fantail is listed as Migratory under the EPBC Act.

Rufous fantail are likely to regularly occur in or move through the Study Area. The number of birds migrating through the Study Area is likely to peak during southward passage which usually occurs in QLD from October to November (Higgins *et al.* 2006). Rufous fantail movement patterns are poorly understood in Central QLD though this species has been recorded during each month of the year in the Rockhampton region.

Rufous fantail's Minor overall risk rating reflects the anticipated regular occurrence within the Study Area, predicted low flight behaviour (below RSA) and minor rating for consequence based on their very large population size, capability to replace lost individuals and non-threatened status at the state and national scale.

Rufous fantail risk assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low	X			X	X	X
Moderate			X			
High		X				
Risk Rating						
Likelihood	Moderate	**Consequence**	Low	**Risk Rating**	Minor	

D2.5 Satin flycatcher

Information on satin flycatcher from Australian wind farms

There are no records of blade strike of satin flycatcher in the available literature from Victoria (Moloney *et al.* 2019) or Tasmania (Hull *et al.* 2013).

Likelihood and Consequence of Impacts

The overall risk rating for satin flycatcher is Minor, based on a Moderate likelihood and Minor consequence of collisions. The rationale for responses to each criterion is as follows:

- Little is known about the height range in which satin flycatcher fly whilst migrating, though the majority of movements are likely to occur below 55 m AGL.
- Satin flycatcher is likely to regularly occur in or move through the Study Area particularly between August to November and February to May.
- Though the satin flycatcher does not congregate in high numbers a large proportion of the population that migrates south of the Study Area annually is likely to migrate through a relatively restricted area along the coast and eastern escarpment of the Great Dividing Range where the majority of suitable habitat is present. Hence, Criterion C is assigned 'moderate'.
- The life-history characteristics of satin flycatcher matches the description for a Low rating for Criterion D (Higgins et al. 2006).
- The total population of satin flycatcher is estimated to exceed 20,000 individuals (Department of the Environment 2015b).
- Satin flycatcher is listed as migratory under the EPBC Act.

Satin flycatcher are likely to regularly occur in or move through the Study Area during their migration south through Queensland between August to November and during northward passage between February to early May (Higgins *et al.* 2006). Satin flycatcher have been recorded in the Rockhampton region during all months though the majority of records are between August to November.

Satin flycatcher's Minor overall risk rating reflects the anticipated regular occurrence within the Study Area, predicted low flight behaviour (below RSA) and minor rating for consequence based on their large population size, capability to replace lost individuals and non-threatened status at the state and national scale.

Satin flycatcher risk assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low	X			X	X	X
Moderate			X			
High		X				
Risk Rating						

Likelihood	Moderate	**Consequence**	Low	**Risk Rating**	Minor

D2.6 Black-faced monarch

Information on black-faced monarch from Australian wind farms

There is no publicly available information on blade strike at wind farms within the black-faced monarch's range in Australia.

Likelihood and Consequence of Impacts

The overall risk rating for black-faced monarch is Minor, based on a Moderate likelihood and Minor consequence of collisions. The rationale for responses to each criterion is as follows:

- Little is known about the height range in which black-faced monarch fly whilst migrating though the majority of movements are likely to occur below 55 m AGL.
- The black-faced monarch is likely to regularly occur in or move through the Study Area particularly between September to November and February to April.
- Though the black-faced monarch does not congregate in high numbers a large proportion of the population that migrates south of the Study Area annually is likely to migrate through a relatively restricted area along the coast and eastern escarpment of the Great Dividing Range where the majority of suitable habitat is present. Hence, Criterion C is assigned 'moderate'.
- The life-history characteristics of the black-faced monarch matches the description for a 'low' rating for Criterion D (Higgins *et al.* 2006).
- The total population of black-faced monarch is estimated to exceed 20,000 individuals (Department of the Environment 2015b).
- Black-faced monarch is listed as migratory under the EPBC Act.

Black-faced monarch are likely to regularly occur in or move through the Study Area particularly during southward passage from September to November and northward passage between February to April (Higgins *et al.* 2006). Black -faced monarch have been recorded during all months in the Rockhampton region barring June and July. The majority of records in the region fall within migratory periods during September to October and March to April.

The black-faced monarch's Minor overall risk rating reflects the anticipated regular occurrence within the Study Area, predicted low flight behaviour (below RSA) and minor rating for consequence based on their large population size, capability to replace lost individuals and non-threatened status at the state and national scale.

Black-faced monarch risk assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low	X			X	X	X
Moderate			X			
High		X				
Risk Rating						

Likelihood	Moderate	**Consequence**	Low	**Risk Rating**	Minor

D2.7 Spectacled monarch

Information on spectacled monarch from Australian wind farms

There is no publicly available information on blade strike at wind farms within the spectacled monarch's range in Australia.

Likelihood and Consequence of Impacts

The overall risk rating for spectacled monarch is Minor, based on a Moderate likelihood and Minor consequence of collisions. The rationale for responses to each criterion is as follows:

- Little is known about the height range in which spectacled monarch fly whilst migrating though the majority of movements are likely to occur below 55 m AGL.
- Spectacled monarch is likely to regularly occur in or move through the Study Area.
- Though the spectacled monarch does not congregate in high numbers a large proportion of the population that migrates south of the Study Area annually is likely to migrate through a relatively restricted area along the coast and eastern escarpment of the Great Dividing Range where the majority of suitable habitat is present. Hence, Criterion C is assigned Moderate.
- The life-history characteristics of spectacled monarch matches the description for a Low rating for-Criterion D (Higgins et al. 2006).
- The total population of spectacled monarch is estimated to exceed 20,000 individuals (Department of the Environment 2015).
- Spectacled monarch is listed as migratory under the EPBC Act.

Spectacled monarch movement patterns are not well known though observations in eastern Australia indicate that a proportion of their population undertakes migratory movements (Higgins *et al.* 2006). Birds on southward passage are likely to pass through the Study Area during September to October and those migrating north are likely to move through the Study Area during March to April (Higgins *et al.* 2006). Individuals that are largely sedentary or those that do not migrate further south or north than Central QLD may be present in the Study Area at any time of year. Spectacled monarch have been recorded during all months in the Rockhampton/Gladstone region.

Spectacled monarch's Minor overall risk rating reflects the anticipated regular occurrence within the Study Area, predicted low flight behaviour (below RSA) and minor rating for consequence based on their large population size, capability to replace lost individuals and non-threatened status at the state and national scale.

Spectacled monarch risk assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low	X			X	X	X
Moderate			X			
High		X				
Risk Rating						
Likelihood	Moderate	**Consequence**	Low	**Risk Rating**	Minor	

D.3 Non-listed Birds

Non-listed birds were included in the risk assessment due to observed flights within the RSA.

D3.1 Wedge-tailed eagle

Information on wedge-tailed eagle from Australian wind farms

The wedge-tailed eagle is commonly reported during mortality monitoring events at wind farms in Australia. Moloney *et al.* (2019) report wedge-tailed eagle as the second most frequently recorded bird species found dead during monitoring from 2003 to 2018 across 15 wind farms in Victoria, with 58 carcasses detected and equating to 10% of all birds found. Using this data, Moloney *et al.* (2019) calculated mortality estimates of 0.06 (95% CI: 0.02–0.41) and 0.1 (95% CI: 0–0.2) individuals per turbine per year at 2 Victorian wind farms.

At 2 wind farms in north-western Tasmania, 18 wedge-tailed eagle carcasses were recorded during monitoring conducted for 3 and 6 years at Bluff Point Wind Farm and Studland Bay Wind Farm respectively (Hull *et al.* 2013). This particular monitoring program modelled a mortality estimate of 1.5 and 1.1 collisions per annum at Bluff Point (37 turbines) and Studland Bay (25 turbines). A 95% turbine avoidance rate closely approximated the observed mean annual mortality rate of 1.6 and 1.1 individuals per annum at each wind farm respectively (Smales *et al.* 2013).

Wedge-tailed eagle occur at the majority of wind farms in Australia however publicly available information on blade strike is restricted to that collected from select Victoria and Tasmania wind farms discussed above.

Likelihood and Consequence of Impacts

The overall risk rating for wedge-tailed eagle is Moderate, based on a High likelihood and Low consequence of collisions. The rationale for responses to each criterion is as follows:

- A high proportion of the wedge-tailed eagle's flight activity is at RSA height.
- Wedge-tailed eagle is a common resident in the Study Area.
- Wedge-tailed eagle is largely sedentary, is widely dispersed within areas of suitable habitat and the habitat itself is widely dispersed.
- The life-history characteristics of the wedge-tailed eagle overlap with certain aspects of both the descriptions for a 'low' and 'high' rating for criterion D (Marchant and Higgins 1993).
- The total population of wedge-tailed eagle is described as very large by Birdlife International (2020) and given its very large distribution (c. 10.6 Mkm^2) its total population is very likely to exceed 20,000 individuals.
- The subspecies of wedge-tailed eagle that occurs in the Study Area is not listed as threatened under the EPBC Act or the NC Act.

Wedge-tailed eagle's Moderate risk rating largely reflects the relatively low consequence that a potentially high frequency of blade strike in the Study Area is likely to have on this species overall.

Wedge-tailed eagle risk assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low			X		X	X
Moderate				X		
High	X	X				
Risk Rating						
Likelihood	High	**Consequence**	Low	**Risk Rating**	Moderate	

D3.2 Other diurnal raptors

Black kite, brown falcon, brown goshawk, nankeen kestrel, pacific baza, peregrine falcon and whistling kite have been recorded flying at RSA height in the Study Area. Grey goshawk and collared sparrowhawk have been recorded in the Study Area below RSA height though each species is likely to occur at RSA height.

Other raptor species that have not been recorded in the Study Area but may occasionally move through the area such as white-bellied sea-eagle, little eagle, square-tailed kite, swamp harrier, spotted harrier, black falcon and Australian hobby are not included in this assessment though are noted to be at risk of blade strike wherever they occur given their flight behaviour.

The Moderate risk rating for these eight raptors reflects the relatively low consequence that blade strike in the Study Area is likely to have on these species overall given their large populations and secure status at State and National level. Variability between species in terms of the potential impact of a set number of collisions on local populations is likely (for example the loss of five grey goshawk would have a greater impact than the loss of five black kite on both species' respective local populations) though overall a low rating for consequence is appropriate for all eight species at the broader scale.

Diurnal raptor risk assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low			All		All barring GG	All
Moderate	GG, CS	BG, CS, PB, PF, GG, WK		All	GG	
High	BF, BG, BK, NK, PB, PF, WK	BF, BK, NK				

Risk Rating						
BF, BG, BK PB, PF, NK, WK	**Likelihood**	High	**Consequence**	Low	**Risk Rating**	Moderate
CS, GG	**Likelihood**	Moderate	**Consequence**	Moderate	**Risk Rating**	Moderate

LEGEND: PB: Pacific baza, BK: black kite, BG: brown goshawk, GG: grey goshawk, CS: collared sparrowhawk, BF: brown falcon, PF: peregrine falcon, NK: nankeen kestrel, WK: whistling kite.

D3.3 Rainbow bee-eater

There is no publicly available information on blade strike at wind farms within the rainbow bee-eater's range in Australia.

The overall risk rank for rainbow bee-eater is Moderate, based on a Moderate likelihood and a Low consequence of collisions.

The rationale for responses to each criterion is as follows:

Rainbow bee-eater risk assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low			X	X	X	X
Moderate	X					
High		X				

Risk Rating					
Likelihood	High	**Consequence**	Low	**Risk Rating**	Moderate

D3.4 Channel-billed Cuckoo

Channel-billed cuckoo are included in the risk assessment as they were observed flying within the RSA. The overall risk rating for channel-billed cuckoo is moderate, based on a high likelihood and low consequence collisions.

Channel-billed cuckoo risk assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low			X		X	X
Moderate		X		X		
High	X					
Risk Rating						

Likelihood	High	Consequence	Low	Risk Rating	Moderate

D3.5 Topknot pigeon

Topknot pigeon are included in the risk assessment as they were observed flying within the RSA. The overall risk rating for topknot pigeon is moderate, based on a high likelihood and low consequence of collisions.

Topknot pigeon risk assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low			X		X	X
Moderate		X		X		
High	X					
Risk Rating						

Likelihood	High	Consequence	Low	Risk Rating	Moderate

D3.6 Other Parrots

Rainbow lorikeet, red-tailed black cockatoo, galah and sulphur-crested cockatoo are common residents in the Study Area which were occasionally recorded flying at RSA height during the bird utilisation survey. Additionally, scaly-breasted lorikeet was observed flying through the RSA.

The overall risk rating for these four species is Minor, based on a Moderate likelihood and Low consequence of collisions.

Parrots risk assessment (rainbow lorikeet, galah, red-tailed black-cockatoo, scaly-breasted lorikeet and sulphur-crested cockatoo)

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low			X		X	X
Moderate	X	X		X		
High						
Risk Rating						
Likelihood	Moderate	**Consequence**	Low	**Risk Rating**	Minor	

D3.7 Common passerines

These five common passerines were regularly recorded in the Study Area during the bird utilisation survey and are included in the risk assessment as they were observed flying at RSA height on at least one occasion.

The overall risk rating for blue-faced honeyeater is Minor, based on a Moderate likelihood and Low consequence of collisions. The overall risk rating for Australian magpie, noisy friarbird, pied currawong, Torresian crow and tree martin is Moderate, based on a High likelihood and Low consequence of collisions.

Common resident passerine risk assessment (blue-faced honeyeater, striated pardalote, pied currawong, Torresian crow, tree martin)

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low	BFH		All	All	All	All
Moderate	AM, NF, PC, TC, TM					
High		All				
Risk Rating						
BFH	**Likelihood**	Moderate	**Consequence**	Low	**Risk Rating**	Minor
AM, NF, PC, TC, TM	**Likelihood**	High	**Consequence**	Low	**Risk Rating**	Moderate

AM: Australian Magpie, BFH: blue-faced honeyeater, NF: Noisy Friarbird, PC: pied currawong, TC: Torresian Crow, TM: tree martin.

D.4 Bats

No bats listed under the EPBC Act and/or the NC Act were detected in the Study Area during bird and bat utilisation surveys or other Project associated surveys and none are considered likely to occur in the Study Area. An additional two species, grey-headed flying fox and ghost bat have been included in the risk assessment (**Section 3.4**) despite their Low likelihood of occurrence within the Study Area.

D4.1 Black flying-fox

Black flying-fox were recorded on two occasions in the Study Area. One was observed on 25 May 2020 flying along a creek line at a height of 25 m AGL after foraging in a fig tree. The second observation was of an individual flying at 50 m AGL on 31 May 2020.

The overall risk rating for black flying-fox is Moderate, based on a High likelihood and Low consequence of collisions.

Black flying-fox risk assessment

	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F
Low			X		X	X
Moderate		X		X		
High	X					
Risk Rating						
Likelihood	High	**Consequence**	Low	**Risk Rating**	Moderate	

D.5 References

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APPENDIX E

Weather Data from Surveys

Table E.1 Weather Conditions at Rockhampton Aero Weather Station (039083) during the summer survey (BoM (a) 2021; BoM (b) 2021)

Date	Temperature (°C)		Wind Direction		Wind Speed (km/h)	
	Minimum	Maximum	9 am	3 pm	9 am	3 pm
26/2/20	24.0	32.8	ESE	E	11	11
27/2/20	24.8	33.7	N	NNE	9	15
28/2/20	23.6	33.7	SE	E	7	11
29/2/20	24.3	32.3	ESE	E	13	20
1/3/20	23.0	32.3	ESE	ESE	20	15
2/3/20	23.2	33.5	SE	E	13	15
3/3/20	23.8	32.4	SE	ENE	11	17
4/3/20	24.8	30.4	SE	ESE	19	13

Table E.2 Weather Conditions at Rockhampton Aero Weather Station (039083) during the spring survey (BoM (c) 2021)

Date	Temperature (°C)		Wind Direction		Wind Speed (km/h)	
	Minimum	Maximum	9 am	3 pm	9 am	3 pm
5/11/20	18.2	34.0	N	N	19	20
6/11/20	19.8	35.2	SSE	NNW	11	11
7/11/20	20.3	30.6	E	ENE	19	17
8/11/20	23.6	28.8	E	ENE	26	20
9/11/20	19.6	27.9	ESE	ENE	24	22
10/11/20	17.9	28.8	ESE	E	17	22
11/11/20	17.7	29.1	E	E	11	17

Table E.3 Weather Conditions at Rockhampton Aero Weather Station (039083) during the spring survey (BoM (c) 2021)

Date	Temperature (°C)		Wind Direction		Wind Speed (km/h)	
	Minimum	Maximum	9 am	3 pm	9 am	3 pm
8/10/21	17.7	32.4	NE	SE	9	13
9/10/21	19.2	30.8	E	NE	11	15
10/10/21	17.5	31.4	NNE	NNE	13	20

Date	Temperature (°C)		Wind Direction		Wind Speed (km/h)	
	Minimum	Maximum	9 am	3 pm	9 am	3 pm
11/10/21	15.4	32.9	N	NNE	11	24
12/10/21	21.4	33.2	E	NNE	2	20
13/10/21	20.9	32.4	NNE	ENE	7	17
14/10/21	22.5	33.4	NNE	ENE	19	20
15/10/21	20.8	35.1	NNW	W	20	26

Table E.4 Weather Conditions at Rockhampton Aero Weather Station (039083) during the summer survey (BoM (c) 2022)

Date	Temperature (°C)		Wind Direction		Wind Speed (km/h)	
	Minimum	Maximum	9 am	3 pm	9 am	3 pm
14/02/22	20.8	31.5	ESE	E	24	26
15/02/22	21.5	31.3	ESE	ESE	26	22
16/02/22	21.7	31.2	ESE	ENE	20	19
17/02/22	22.1	32.6	E	NE	19	17
18/02/22	22.3	33.8	ESE	ENE	11	11
19/02/22	22.4	32.7	ESE	ENE	13	20
20/02/22	22.0	32.4	ESE	ENE	17	19
21/02/22	21.9	33.8	E	ENE	13	13

APPENDIX F

Species List

Common Name	Scientific Name	NC Act Status	EPBC Act Status	Observation Location																
				NORTH							POM							BC		Incidental /Other
				1	2	3	4	6	7	8	1	2	3	4	5	8	9	1	2	
Birds																				
apostlebird	*Struthidea cinerea*	Least Concern	-												X					X
Australasian figbird	*Sphecotheres vieilloti*	Least Concern	-			X	X													X
Australasian grebe	*Tachybaptus novaehollandiae*	Least Concern	-																	X
Australasian pipit	*Anthus novaeseelandiae*	Least Concern	-	X		X	X													X
Australian brush-turkey	*Alectura lathami*	Least Concern	-											X						X
Australian bustard	*Ardeotis australis*	Least Concern	-																	X
Australian king-parrot	*Alisterus scapularis*	Least Concern	-					X			X	X	X	X						X
Australian magpie	*Gymnorhina tibicen*	Least Concern	-	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
Australian owlet-nightjar	*Aegotheles cristatus*	Least Concern	-																	X
Australian wood duck	*Chenonetta jubata*	Least Concern	-																	X
barking owl	*Ninox connivens*	Least Concern	-																	X
bar-shouldered dove	*Geopelia humeralis*	Least Concern	-								X			X						
black kite	*Milvus migrans*	Least Concern	-														X			X
black-chinned honeyeater	*Melithreptus gularis*	Least Concern	-																	X
black-faced cuckoo-shrike	*Coracina novaehollandiae*	Least Concern	-	X		X		X	X		X		X	X	X	X		X	X	X
black-faced woodswallow	*Artamus cinereus*	Least Concern	-																	X
blue-faced honeyeater	*Entomyzon cyanotis*	Least Concern	-				X		X		X			X	X	X			X	X
blue-winged kookaburra	*Dacelo leachii*	Least Concern	-										X		X					X

Common Name	Scientific Name	NC Act Status	EPBC Act Status	Observation Location																
				NORTH							POM							BC		Incidental /Other
				1	2	3	4	6	7	8	1	2	3	4	5	8	9	1	2	
brolga	*Antigone rubicunda*	Least Concern	-																	X
brown cuckoo-dove	*Macropygia phasianella*	Least Concern	-											X						X
brown falcon	*Falco berigora*	Least Concern	-		X		X	X	X			X			X		X		X	X
brown goshawk	*Accipiter fasciatus*	Least Concern	-									X	X							X
brown honeyeater	*Lichmera indistincta*	Least Concern	-				X		X											X
brown quail	*Coturnix ypsilophora*	Least Concern	-			X							X		X					X
brown songlark	*Cincloramphus cruralis*	Least Concern	-				X													
brown treecreeper	*Climacteris picumnus*	Least Concern	-											X						
budgerigar	*Melopsittacus undulatus*	Least Concern	-																	X
buff-rumped thornbill	*Acanthiza reguloides*	Least Concern	-																X	
bush stone-curlew	*Burhinus grallarius*	Least Concern	-																	X
cattle egret	*Bubulcus ibis*	Least Concern	-																	X
channel-billed cuckoo	*Scythrops novaehollandiae*	Least Concern	-	X	X		X		X		X		X	X	X	X				X
cicadabird	*Coracina tenuirostris*	Least Concern	-		X		X	X	X		X		X	X			X		X	X
collared sparrowhawk	*Accipiter cirrocephalus*	Least Concern	-								X				X					X
common bronzewing	*Phaps chalcoptera*	Least Concern	-											X						X
crested pigeon	*Ocyphaps lophotes*	Least Concern	-	X																X
dollarbird	*Eurystomus orientalis*	Least Concern	-	X				X						X	X					X
double-barred finch	*Taeniopygia bichenovii*	Least Concern	-												X					X

Common Name	Scientific Name	NC Act Status	EPBC Act Status	Observation Location																
				NORTH							POM							BC		Incidental /Other
				1	2	3	4	6	7	8	1	2	3	4	5	8	9	1	2	
dusky woodswallow	*Artamus cyanopterus*	Least Concern	-																	X
eastern barn owl	*Tyto delicatula*	Least Concern	-																	X
eastern koel	*Eudynamys orientalis*	Least Concern	-	X	X	X	X				X	X	X	X	X		X			X
eastern yellow robin	*Eopsaltria australis*	Least Concern	-																	X
emerald dove	*Chalcophaps indica*	Least Concern	-																	X
emu	*Dromaius novaehollandiae*	Least Concern	-		X															X
fairy gerygone	*Gerygone palpebrosa*	Least Concern	-																	X
fan-tailed cuckoo	*Cacomantis flabelliformis*	Least Concern	-	X			X	X	X		X		X	X	X	X	X	X	X	X
forest kingfisher	*Todiramphus macleayii*	Least Concern	-	X			X	X	X		X		X	X	X	X		X	X	X
galah	*Eolophus roseicapilla*	Least Concern	-										X		X	X				X
glossy black-cockatoo	*Calyptorhynchus lathami erebus*	Vulnerable	-											X						X
golden whistler	*Pachycephala pectoralis*	Least Concern	-																	X
green catbird	*Ailuroedus crassirostris*	Least Concern	-																	X
grey butcherbird	*Cracticus torquatus*	Least Concern	-												X					X
grey fantail	*Rhipidura albiscapa*	Least Concern	-																	X
grey goshawk	*Accipiter novaehollandiae*	Least Concern	-					X												X
grey shrike-thrush	*Colluricincla harmonica*	Least Concern	-				X		X		X		X	X						X
grey-crowned babbler	*Pomatostomus temporalis*	Least Concern	-	X																
ground cuckoo-shrike	*Coracina maxima*	Least Concern	-			X													X	

Common Name	Scientific Name	NC Act Status	EPBC Act Status	Observation Location																
				NORTH							POM							BC		Incidental /Other
				1	2	3	4	6	7	8	1	2	3	4	5	8	9	1	2	
Horsfield's bronze-cuckoo	*Chalcites basalis*	Least Concern	-																	X
laughing kookaburra	*Dacelo novaeguineae*	Least Concern	-	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
leaden flycatcher	*Myiagra rubecula*	Least Concern	-	X				X	X			X	X	X		X				X
Lewin's honeyeater	*Meliphaga lewinii*	Least Concern	-				X	X	X		X	X	X	X	X		X			X
little corella	*Cacatua sanguinea*	Least Concern	-																	X
little friarbird	*Philemon citreogularis*	Least Concern	-								X									X
little lorikeet	*Glossopsitta pusilla*	Least Concern	-																	X
little shrike-thrush	*Colluricincla megarhyncha*	Least Concern	-										X	X						X
magpie-lark	*Grallina cyanoleuca*	Least Concern	-												X					X
masked lapwing	*Vanellus miles*	Least Concern	-												X					X
masked woodswallow	*Artamus personatus*	Least Concern	-																	X
mistletoebird	*Dicaeum hirundinaceum*	Least Concern	-	X	X	X	X	X	X		X	X		X	X	X		X	X	X
nankeen kestrel	*Falco cenchroides*	Least Concern	-	X		X	X				X		X		X	X		X	X	X
noisy friarbird	*Philemon corniculatus*	Least Concern	-	X	X		X				X	X	X	X	X	X	X		X	X
noisy miner	*Manorina melanocephala*	Least Concern	-	X	X	X	X				X	X	X		X	X		X	X	X
olive-backed oriole	*Oriolus sagittatus*	Least Concern	-																	X
Pacific baza	*Aviceda subcristata*	Least Concern	-				X	X												X
Pacific black duck	*Anas superciliosa*	Least Concern	-																	X
painted button-quail	*Turnix varius*	Least Concern	-		X															X

Common Name	Scientific Name	NC Act Status	EPBC Act Status	Observation Location																
				NORTH							POM							BC		Incidental /Other
				1	2	3	4	6	7	8	1	2	3	4	5	8	9	1	2	
pale-headed rosella	*Platycercus adscitus*	Least Concern	-			X		X			X	X	X	X	X			X	X	X
pallid cuckoo	*Cacomantis pallidus*	Least Concern	-																	X
peaceful dove	*Geopelia striata*	Least Concern	-		X	X					X			X						X
peregrine falcon	*Falco peregrinus*	Least Concern	-								X		X	X						X
pheasant coucal	*Centropus phasianinus*	Least Concern	-	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
pied butcherbird	*Cracticus nigrogularis*	Least Concern	-	X	X	X	X	X			X		X	X	X	X	X	X	X	X
pied currawong	*Strepera graculina*	Least Concern	-	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
plumed whistling-duck	*Dendrocygna eytoni*	Least Concern	-																	X
plum-headed finch	*Neochmia modesta*	Least Concern	-																	X
rainbow bee-eater	*Merops ornatus*	Least Concern	-			X			X		X		X	X	X	X		X		X
rainbow lorikeet	*Trichoglossus moluccanus*	Least Concern	-	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
red-backed fairy-wren	*Malurus melanocephalus*	Least Concern	-				X	X	X				X	X	X			X	X	X
red-browed finch	*Neochmia temporalis*	Least Concern	-					X					X							X
red-capped robin	*Petroica goodenovii*	Least Concern	-																	X
red-tailed black-cockatoo	*Calyptorhynchus banksii*	Least Concern	-						X					X		X		X		X
red-winged parrot	*Aprosmictus erythropterus*	Least Concern	-													X				
restless flycatcher	*Myiagra inquieta*	Least Concern	-								X		X							
rose robin	*Petroica rosea*	Least Concern	-											X						X
rose-crowned fruit-dove	*Ptilinopus regina*	Least Concern	-																	X

Common Name	Scientific Name	NC Act Status	EPBC Act Status	Observation Location																
				NORTH							POM							BC		Incidental /Other
				1	2	3	4	6	7	8	1	2	3	4	5	8	9	1	2	
rufous fantail	*Rhipidura rufifrons*	Special Least Concern	Migratory																	X
rufous songlark	*Cincloramphus mathewsi*	Least Concern	-																	X
rufous whistler	*Pachycephala rufiventris*	Least Concern	-						X		X			X						X
scaly-breasted lorikeet	*Trichoglossus chlorolepidotus*	Least Concern	-				X													X
scarlet honeyeater	*Myzomela sanguinolenta*	Least Concern	-						X				X	X						X
silvereye	*Zosterops lateralis*	Least Concern	-					X												X
southern boobook	*Ninox boobook*	Least Concern	-																	X
spangled drongo	*Dicrurus bracteatus*	Least Concern	-			X		X	X		X	X	X	X	X	X		X		X
spectacled monarch	*Symposiachrus trivirgatus*	Special Least Concern	Migratory																	X
spotted bowerbird	*Ptilonorhynchus maculatus*	Least Concern	-																	X
spotted quail-thrush	*Cinclosoma punctatum*	Least Concern	-																	X
squatter pigeon	*Geophaps scripta scripta*	Vulnerable	Vulnerable																	X
straw-necked ibis	*Threskiornis spinicollis*	Least Concern	-																	X
striated pardalote	*Pardalotus striatus*	Least Concern	-	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X
sulphur-crested cockatoo	*Cacatua galerita*	Least Concern	-	X		X	X	X			X	X	X	X	X	X				X
tawny frogmouth	*Podargus strigoides*	Least Concern	-									X				X	X			X
topknot pigeon	*Lopholaimus antarcticus*	Least Concern	-											X						X

Common Name	Scientific Name	NC Act Status	EPBC Act Status	Observation Location																
				NORTH							POM							BC		Incidental /Other
				1	2	3	4	6	7	8	1	2	3	4	5	8	9	1	2	
Torresian crow	*Corvus orru*	Least Concern	-	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
tree martin	*Petrochelidon nigricans*	Least Concern	-						X											X
varied sittella	*Daphoenositta chrysoptera*	Least Concern	-					X					X		X	X				X
varied triller	*Lalage leucomela*	Least Concern	-				X							X						
wedge-tailed eagle	*Aquila audax*	Least Concern	-	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
weebill	*Smicrornis brevirostris*	Least Concern	-						X						X	X				
welcome swallow	*Hirundo neoxena*	Least Concern	-																	X
whistling kite	*Haliastur sphenurus*	Least Concern	-												X		X			X
white-bellied cuckoo-shrike	*Coracina papuensis*	Least Concern	-																	X
white-breasted woodswallow	*Artamus leucorynchus*	Least Concern	-																	X
white-browed scrubwren	*Sericornis frontalis*	Least Concern	-					X						X						X
white-browed treecreeper	*Climacteris affinis*	Least Concern	-											X						
white-cheeked honeyeater	*Phylidonyris niger*	Least Concern	-								X		X		X				X	
white-eared honeyeater	*Nesoptilotis leucotis*	Least Concern	-								X		X	X	X				X	X
white-faced heron	*Egretta novaehollandiae*	Least Concern	-																	X
white-throated gerygone	*Gerygone olivacea*	Least Concern	-													X				X
white-throated honeyeater	*Melithreptus albogularis*	Least Concern	-	X	X		X	X	X		X	X	X	X	X	X		X	X	X
white-throated needletail	*Hirundapus caudacutus*	Vulnerable	Vulnerable, Migratory	X			X		X			X				X				X

Common Name	Scientific Name	NC Act Status	EPBC Act Status	Observation Location																
				NORTH							POM							BC		Incidental /Other
				1	2	3	4	6	7	8	1	2	3	4	5	8	9	1	2	
white-throated nightjar	*Eurostopodus mystacalis*	Least Concern	-																	X
white-throated treecreeper	*Cormobates leucophaea*	Least Concern	-				X	X	X		X		X	X	X	X		X	X	X
white-winged chough	*Corcorax melanorhamphos*	Least Concern	-																	X
willie wagtail	*Rhipidura leucophrys*	Least Concern	-																	X
wonga pigeon	*Leucosarcia melanoleuca*	Least Concern	-											X						X
yellow-rumped thornbill	*Acanthiza chrysorrhoa*	Least Concern	-																	X
yellow-tailed black-cockatoo	*Calyptorhynchus funereus*	Least Concern	-																	X
zebra finch	*Taeniopygia guttata*	Least Concern	-																	X
Microbats																				
bristle-faced free-tailed bat	*Mormopterus eleryi*	Least Concern	-								X	X				X				X
chocolate wattled bat	*Chalinolobus morio*	Least Concern	-		X	X			X			X	X	X	X	X	X			X
eastern bent-wing bat	*Miniopterus orianae*	Least Concern	-		X	X		X	X			X	X	X	X	X	X			X
eastern cave bat	*Vespadelus troughtoni*							X	X				X		X					
eastern free-tailed bat	*Mormopterus ridei*	Least Concern	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X
eastern horseshoe-bat	*Rhinolophus megaphyllus*	Least Concern	-						X		X	X	X	X			X			X
Gould's wattled bat	*Chalinolobus gouldii*	Least Concern	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X
hoary wattled bat	*Chalinolobus nigrogriseus*	Least Concern	-	X	X	X	X	X	X		X	X	X	X	X	X	X			X
inland broad-nosed bat	*Scotorepens balstoni*	Least Concern	-			X		X	X		X	X	X	X	X	X	X			X
little bent-wing bat	*Miniopterus australis*	Least Concern	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X

Common Name	Scientific Name	NC Act Status	EPBC Act Status	Observation Location															
				NORTH							POM							BC		Incidental /Other
				1	2	3	4	6	7	8	1	2	3	4	5	8	9	1	2	
little broad-nosed bat	*Scotorepens greyii*	Least Concern	-	X	X	X	X	X	X		X	X	X	X	X	X	X			X
little pied bat	*Chalinolobus picatus*	Least Concern	-		X			X	X		X	X	X	X	X	X	X			X
northern broad-nosed bat	*Scotorepens sanborni*	Least Concern	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X
northern freetail bat	*Chaerephon jobensis*	Least Concern	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X
northern free-tailed bat	*Mormopterus lumsdenae*	Least Concern	-	X	X	X	X				X	X	X	X	X	X	X			X
-	*Nyctophilus sp. (N. geoffroyi or N. gouldi)*	Least Concern	-		X	X					X	X	X	X	X	X	X			X
south-eastern broad-nosed bat	*Scotorepens orion*	Least Concern	-					X	X		X		X		X					
southern horseshoe bat	*Rhinolophus megaphyllus megaphyllus*	Least Concern	-											X						
Troughton's sheathtail bat	*Taphozous troughtoni*	Least Concern	-									X			X					
yellow-bellied sheathtail bat	*Saccolaimus flaviventris*	Least Concern	-	X	X	X			X		X	X	X	X	X	X	X			X

umwelt

umwelt
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APPENDIX B

Mount Hopeful Wind Farm Turbine
Collision Risk Assessment for White-throated Needletail (Biosis, 2022)

Mount Hopeful Wind Farm
Turbine Collision Risk Assessment for White-throated Needletail

Prepared for Umwelt Pty Ltd

22 Februart 2023

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1. Introduction

This document presents an assessment of turbine collision risk for White-throated Needletail *Hirundapus caudacutus* at the proposed Mount Hopeful Wind Farm Project in Queensland. The species is a matter of national environmental significance as it is listed as vulnerable and migratory under provisions of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

A systematic regime was used by ecologists from Umwelt to collect data for birds in flight at the Mount Hopeful Wind Farm site. White-throated Needletails were documented flying within the height of rotors of the turbines proposed for the project. Some collisions of White-throated Needletails with wind turbines have been documented in Australia (Hull et al. 2013; Moloney et al. 2019; Threatened Species Scientific Committee 2019) and thus there is a potential risk of collisions with turbines at the Mount Hopeful Wind Farm.

Collision risk assessment is provided here for the species for two different turbines that are under consideration.

1.1 Background to quantitative risk modelling

Collisions of birds and bats with wind turbines have been documented to occur at various frequencies around the world. Quantitative modelling to estimate the number of collision mortalities of threatened and non-threatened taxa is widely used as part of environmental impact assessments for proposed wind energy facilities (Masden & Cook 2016).

The impact of any collisions on the viability of threatened and non-threatened fauna populations is more important than determination of simple numbers of mortalities, and population models can be used in combination with results of collision risk models to evaluate such impacts, but population modelling would be a separate exercise to the collision risk modelling presented here (Smales 2017).

Mathematical modelling of risk is intended to provide an articulate, transparent and replicable evaluation of what may occur in the real world. The rationale behind projections is explicitly stated in the mathematics of a model, which means that the logical consistency of the predictions can be easily evaluated. The explicit nature of inputs and rigour entailed in modelling means that the process is replicable and consistent and that it is open to analysis, criticism or modification when new information becomes available. Modelling is designed as a mechanism to evaluate uncertainties – if there was no uncertainty there would be no need to use a model. As a consequence of uncertainty in various parameters, some assumptions are required and while it is necessary to include some assumptions and arbitrary choices when deciding on the structure and parameters of a model, these choices are explicit. To the extent feasible, assumptions are informed by the best available information.

Models are also valuable for their heuristic capacities as they focus attention on important processes and parameters entailed in risk (Brook et al. 2002). Their very nature facilitates incorporation of information as it is learnt (Burgman 2005) and refinements should thus be expected of any model. The only alternative to a quantitative modelling approach is one of qualitative subjective judgement. All the benefits of using mathematical modelling outlined above are difficult, if not impossible to achieve with a purely qualitative assessment.

Most factors related to the layout, dimensions and geometry of turbines are known. The risk modelling detailed here entails the use of informed assumptions related particularly to the flights of birds. The bird utilisation data collected from the site provides an empirical basis for extrapolations required for use in the model. We consider the assumptions and values used are reasonable and they are informed by available information about the ecology of the species. However, it should be borne in mind that data for birds collected at the site can only ever be a sample of the relevant species activities there and that the value of the sample as representative of those activities over the long-term is subject to uncertain environmental variables and, potentially to the species response to a wind farm, if it is built.

1.2 Turbine collision risk model

The risk of White-throated Needletails colliding with turbines at the proposed Mount Hopeful Wind Farm project has been assessed using the Biosis Deterministic Collision Risk Model. The model was first developed in 2002 and has been refined over time to incorporate new data and knowledge, and has been applied at a wide range of proposed wind farm sites in Australia. A full description of the model (Smales et al. 2013) is provided in Appendix 1.

1.2.1 Overview of the model

The collision risk model takes account of bird flights that occur within the height zone that will be occupied by turbines. Data for the number of flights and their heights was documented by a regime of fixed-time point counts at locations representative of future turbine locations across the site. The model uses the empirical sample of flight data for the species and extrapolates that to determine a potential number of such flights that might occur over an entire 12-month period. White-throated Needletails migrate from the northern hemisphere to Australia for their non-breeding season and routinely are annually present in south-eastern Australia between October and March/April (Threatened Species Scientific Committee 2019). The model takes this seasonal presence into account.

In the model, the turbine is decomposed into its static and dynamic components. The entire turbine (including the tower, nacelle and the rotor when stationary) represents the static component. The dynamic component is the volume swept by the leading edge of the rotor blades in the time it takes the species of interest to pass through the airspace in which the rotor sweeps.

Since the turbine tower below rotor swept height is always a static component and poses minimal collision risk, the model takes this into account by dividing flights into those below turbine rotor height, and those within the height zone swept by turbine rotors and allocates different risk rates to these height zones.

The risk assessment accounts for a combination of variables that are specific to the proposed wind farm and to data for birds from the site. They include the following:

- The numbers of flights of the species below rotor height, and for which just the lower portion of turbine towers may present a collision risk.
- The numbers of flights at heights within the zone swept by turbine rotors, and for which the upper portion of towers, nacelles and rotors present a collision risk.
- The numbers of bird movements-at-risk, as recorded during timed point counts, extrapolated to determine an estimated number of movements-at-risk the species makes in an entire year. Account is taken of the portion of the year that birds may be present in Australia and they may thus be at risk.

- The mean area (m^2 per turbine), of tower, nacelle and stationary rotor blades of a wind generator that present a risk to birds. Thus, the mean area presented by a turbine is between the maximum (where the direction of the bird is perpendicular to the plane of the rotor sweep) and the minimum (where the direction of the bird is parallel to the plane of the rotor sweep). The mean presented area is determined from turbine specifications supplied to Biosis for the specific make and model of turbine. It represents the average area presented to an incoming flight from any direction.
- The additional area (m^2 per turbine) presented by the movement of rotors during the potential flight of a bird through a turbine. This information is determined via a calculation involving species-specific, independent parameters of flight speed and body length and supplied turbine specifications.
- The model assumes that all turbines at the site represent equal risk.
- A calculation of the average number of turbines a bird is likely to encounter in a given flight through the site. This is based on the scattered configuration of turbines in the landscape and the total number of turbines proposed for the project.

1.2.2 Avoidance rate

Results are provided for various avoidance rates. Avoidance rate is the capacity for a bird to avoid a collision, whether that occurs due to a cognitive response on the part of a bird or not. An avoidance rate of 0.95 would equate to one flight in 20 in which a bird takes no action to avoid a turbine and a 0.999 avoidance rate equates to one flight in 1000 in which it would not avoid a turbine.

It should be noted that internationally there is very little empirical evidence for the actual avoidance rate for any bird species and for this reason it is prudent to provide a range of estimates that are considered to be reasonable. The evidence that is available suggests that avoidance capacity is species-specific and that the great majority of birds have avoidance capability that is higher than 0.98. Overseas, avoidance rates of greater than 0.99 have been demonstrated to be applicable to a variety of seabirds (Cook et al. 2014).

Based on experience with a wide range of bird species, it is certain that virtually all species have high capacity to avoid collision with the static components of turbines. White-throated Needletails are highly agile, aerial birds and it is not considered likely that they would collide with stationary turbines. For this reason, an avoidance rate of 0.9999 has been applied to static turbine components in the modelling regardless of the different dynamic avoidance rates applied. Various avoidance rates are modelled for the dynamic turbine components because, while it is reasonable to assume that White-throated Needletails can avoid a moving rotor most of the time, the actual rate at which they can do so is not certain. For this reason, results are provided for 0.990, 0.995 and 0.999 avoidance rates for the dynamic components (moving rotor) of turbines.

1.2.3 Result metrics

Bird movement data is measured by the number of flights recorded at the site. Only when a reasonable estimate can be made for the number of individuals that might occur at the site can the model incorporate that to provide results expressed as an annual estimate of the number of individuals that might collide (otherwise the results remain expressed as the simple number of flights at risk). In order to provide results in terms of an annual estimate of bird collisions, a site-population estimate for White-throated Needletails has been applied for the present modelling.

The model cannot forecast the frequency of collisions around the predicted annual average and it is important to recognize that the number of any actual collisions that might occur can be expected to vary from year to year in a distribution around the average.

All results are provided to three significant figures simply to permit differences between them to be apparent. This should not be taken to indicate a measure of precision in result values. Output values represent annual 'average' results and, of course actual bird fatalities will always be measured in numbers of individuals and that may vary from year-to-year in a distribution around the mean.

2. Model inputs and assumptions

The Biosis collision risk model requires a range of numeric inputs, to quantify the number of turbines, key dimensions of turbines, and to estimate bird utilisation characteristics, including the number of flights within- and below rotor swept height for the species under consideration.

2.1 Wind farm and turbine parameters

Collision risk modelling has been undertaken for two different turbines, both of which are 6.0 megawatt machines. In both options the total number of turbines proposed for the project is 63.

While the rotor spans of the two turbines are of similar size, one (turbine A) is proposed to have a hub height of 166 metres, while the hub height of the other (turbine B) is proposed to be at 148 metres above ground level.

The collision risk model requires input values for 36 turbine parameters that include number and layout of turbines and multiple aspects of turbine dimensions and geometry.

For either turbine, the landscape configuration of the proposed project will be a scattered array of turbines across the site. In this type of array, a bird has a potential to encounter multiple turbines in a given flight.

2.2 Bird data

Flight data for all diurnal birds, including White-throated Needletails, were collected by ecologists from Umwelt during a regime of fixed-time point counts across the Mount Hopeful Wind Farm site. Each point count was 60 minutes long and a total of 13,560 minutes of point counts were undertaken.

The Conservation Advice for White-throated Needletail (TSSC 2019) notes that it is difficult to systematically survey for the species in Australia. At least in part, this is because during their annual sojourns in Australia they are highly mobile within their distribution and their occurrence at any given location is largely unpredictable. Nonetheless, the species was recorded at the Mount Hopeful site on 16 occasions in the months of November, January, February and March. This almost spans the routine annual period in which the species occurs in Australia (Yamaguchi et al. 2021). That study indicates that the species is generally absent from Queensland by April and results from the Mount Hopeful site are consistent with that information. For the purpose of the model it was assumed that the species may occur at the site during six months of the year.

The number of White-throated Needletails recorded varied between observations from one individual to a flock of 180, with a mode of one and a mean of 28 birds. There were many counts during the relevant months in which the species was not detected. Due to its geographic mobility, this level of variation is usual for the species.

Many observations were of multiple individuals, so the data includes a total of 447 records of White-throated Needletail flights. Of these, 131 flights were recorded at heights between 250 and 1000 metres which are higher than the top rotor height of either turbine and are not considered to be at risk of collision. The remaining 316 records were between 15 and 200 metres high and they provide the empirical basis for collision risk modelling.

In accordance with the highest and lowest tip heights of the blades of the two turbines, different proportions of the documented flights of White-throated Needletails would be below rotor height or within it. The risk profile for the two turbine options thus differs slightly. Distribution of White-throated Needletail flights within relevant height bands are shown in Table 2.

Table 2 Flight heights of White-throated Needletails documented at Mount Hopeful Wind Farm site relative to rotor heights of two turbines under consideration

Turbine	Rotor height span (metres above ground level)	Flights recorded below rotor-swept height	Flights recorded within rotor-swept height
Turbine A	85 - 247	75	241
Turbine B	66 - 230	46	270

It is important to note that the differences in flight heights below- and within rotor swept height as they relate to the two turbines (Table 2) are due to a single observation of 29 birds recorded at 70 metres height. This record was thus below rotor swept height of turbine A, but within rotor swept height of the turbine B.

The model accounts for forward motion of a bird through the airspace occupied by a turbine and calculates the time taken for a bird of a given length and flight speed to pass through that airspace. For this reason, the length of the bird and an average flight speed are required inputs to the model. White-throated Needletail is modelled with a bill-tip to tail-tip length of 21 centimetres. The species is considered to be the world's fastest bird in flight, attaining speeds of up to 130 kilometres per hour (Australian Museum 2020). A lower flight speed results in an increased potential exposure to collision risk, so for the purposes of conservatism, modelling has assumed a mean flight-speed of 100 kilometres per hour for the species.

2.3 Site-population estimate

In order to provide results in terms of an annual estimate of bird collisions, a site-population estimate for White-throated Needletails was applied for the present modelling. The number of individuals that may occur at the site varies substantially and it is possible that it is also highly unpredictable from one year to another. The most recent total Australian (and global) population estimate for the species is 41,000 (range of 20,000 – 61,000) (Tarburton and Garnett 2021). For the purposes of the modelling exercise, a site-population of 1000 individuals was used and is considered to be conservative as the greatest number of White-throated Needletails documented on any one occasion at the Mount Hopeful site was far fewer than this number.

3. Model results

Collision risk model results for White-throated Needletail are shown in Table 3. The results are expressed as the projected annual number of potential collisions.

Table 31 Annual collision risk model results for White-throated Needletails for two turbine options for Mount Hopeful Wind Farm

Turbine option	Estimated number of collisions per annum at dynamic rotor avoidance rate		
	0.990	0.995	0.999
Turbine A	0.172	0.089	0.022
Turbine B	0.166	0.083	0.017

We are not aware of any empirical data from any wind energy facilities that indicate a definitive avoidance capacity for White-throated Needletails, but the species is very agile in flight and it is probable that their capacity to avoid collisions is within the range of modelled avoidance rates set out in Table 3. At a lower, conservative extreme, the results at 0.99 dynamic avoidance rate are about 0.17 collisions per annum for White-throated Needletails for either of the two turbines. This would equate to an approximate average of one White-throated Needletail collision in 5.9 years. Results for the highest avoidance rate of 0.999 of approximately 0.02 would equate to an approximate average of one White-throated Needletail collision in 50 years.

Results of the collision risk modelling indicate little difference in risk to White-throated Needletails between the two turbine options. As noted above, the differences in flight heights below- and within rotor swept height as they relate to the two turbines are due to a single observation of 29 birds recorded at 70 metres height. Thus, the small difference between modelled results cannot be considered to be a reliable indicator of different risks due to the different rotor heights of the two turbines.

Rather than rotor-height, the primary factor influencing the slightly different results for the two turbines is the higher rotor speed of turbine A, with an average of 12.1 revolutions per minute, compared to an average rotor speed of 9.7 revolutions per minute for turbine B. As the average flight speed of the species is held as a constant in the risk model, greater rotor speed exposes a bird interacting with a turbine to a heightened level of collision risk.

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Appendix 1

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Wind Energy and Wildlife Conservation

A Description of the Biosis Model to Assess Risk of Bird Collisions With Wind Turbines

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ABSTRACT We describe the model of Biosis Propriety Limited for quantifying potential risk to birds of collisions with wind turbines. The description follows the sequence of the model's processes from input parameters, through modules of the model itself. Aspects of the model that differentiate it from similar models are the primary focus of the description. These include its capacity to evaluate risk for multi-directional flights by its calculation of a mean presented area of a turbine; its use of bird flight data to determine annual flux of movements; a mathematical solution to a typical number of turbines that might be encountered in a given bird flight; capacity to assess wind-farm configurations ranging from turbines scattered in the landscape to linear rows of turbines; and the option of assigning different avoidance rates to structural elements of turbines that pose more or less risk. We also integrate estimates of the population of birds at risk with data for numbers of their flights to predict a number of individual birds that are at risk of collision. Our model has been widely applied in assessments of potential wind-energy developments in Australia. We provide a case history of the model's application to 2 eagle species and its performance relative to empirical experience of collisions by those species.

KEY WORDS bird, collision, model, risk, turbine, wind energy.

A number of mathematical models have been developed for the purposes of either describing the interaction of a bird with a wind turbine or to predict the risks of bird collisions with turbines (Tucker 1996*a*, *b*; Podolsky 2003, 2005; Bolker et al. 2006; Band et al. 2007). Tucker (1996*a*, *b*) and Band et al. (2007) detailed their models in the peer-reviewed literature. The collision risk model developed by Biosis Propriety Limited has been widely used to assess wind-energy developments in Australia since 2002, but it has not previously been described in detail. Given high levels of interest in effects of wind turbines on fauna, we believe it is important for the model to be accessible.

Our model provides a predicted number of collisions between turbines and a local or migrating population of birds. It has the potential to be modified to accommodate Monte-Carlo simulation, although at its core it uses a deterministic approach. It is modular by design, and allows various customizations, depending upon the unique configuration of the wind facility and characteristics of the taxa modeled.

The initial calculation involves species-specific parameters for speed and size of birds and specifications of the turbine, including its dimensions and rotational speed of its blades. Using these parameters, we derive the mean area of turbine presented to a bird in flight. This allows the model to accommodate flight approaches from any potential direction. Alternatively, unidirectional flights can be modeled by using the relevant turbine surface area presented to birds approaching from a given direction.

Data for bird flights are collected at the wind-farm site according to a specific and consistent field methodology. These data are used to determine the flux (density) of bird flights. When combined with turbine specifications, this yields the probability of collision during a single flight–turbine interaction. The density flux approach has not been used for this application previously.

The number of movements at risk of collision with one turbine is then scaled according to a typical number of turbines that a bird might encounter in a given flight. This is further refined by a metric for the capacity of the particular species to avoid collisions. Where a population census or estimate is available for the number of birds that may be at risk, a further deduction is used to attribute the number of flights-at-risk to individuals, and hence provide a final model output as the number of individuals at risk of collisions. The ability to transform from flights-at-risk to individuals-at-risk has been uniquely developed and applied as a routine component of our model.

DESCRIPTION OF THE MODEL

The model requires data for input parameters and, using these, functions in a sequence of modules (Fig. 1).

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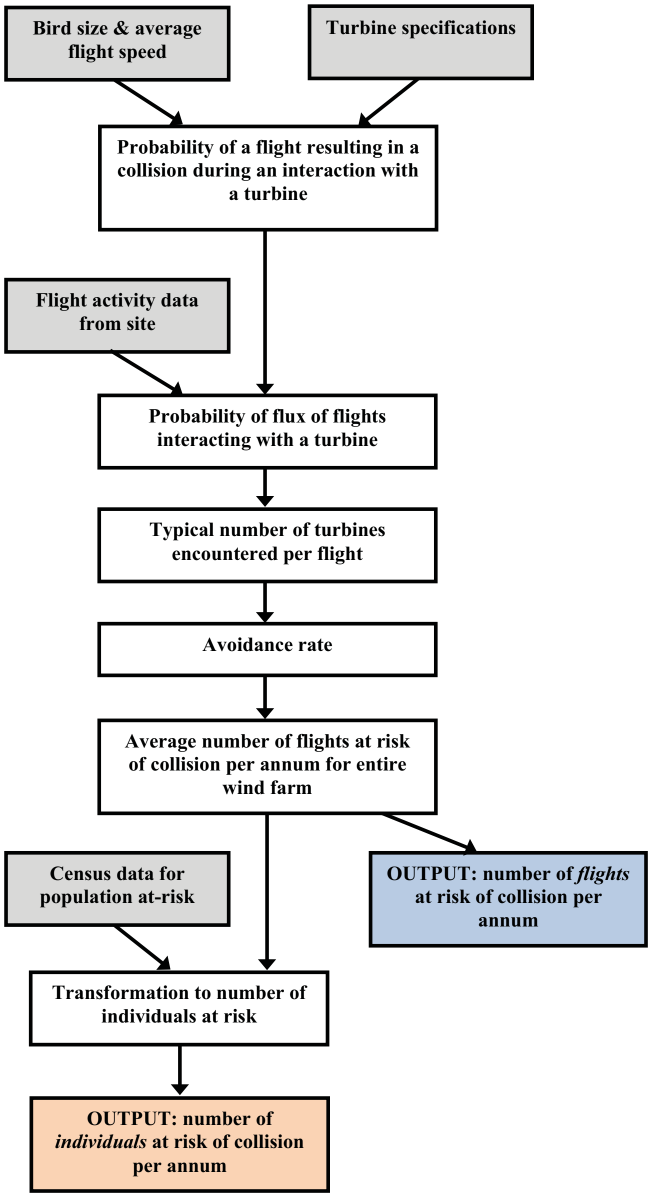

Figure 1. Overview of the collision risk model that quantifies risk to birds of colliding with wind turbines, showing input parameters (gray boxes), mod ules, and sequence.

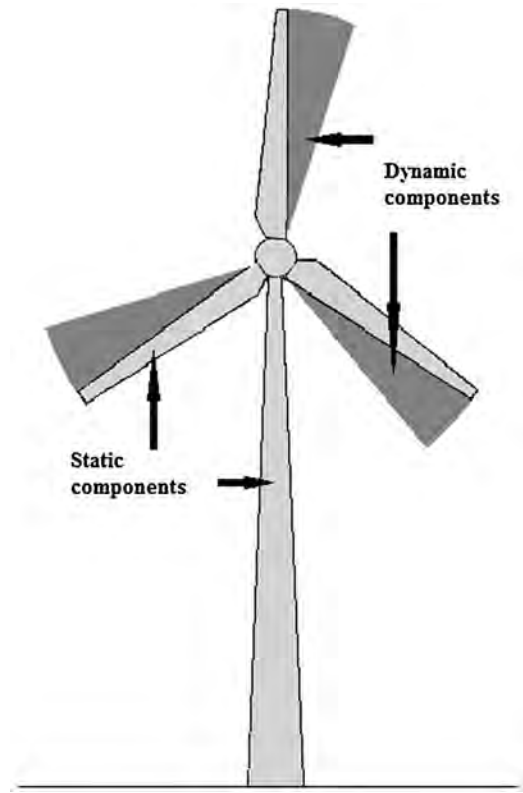

Figure 2. Schematic indication of the static and dynamic components of a wind turbine that may be encountered by a flying bird. The dynamic com ponent is the area swept by rotor blades during the time that a bird of a particular species would take to pass through the rotor swept zone.

Model Inputs

Turbine parameters.—The primary risk faced by a flying bird, whether it may strike or be struck by a turbine, is that the machine presents a potential obstacle in its path. Ultimately this equates to the surface area of the turbine presented to the bird from whatever its angle of approach. Other models, such as probably Band et al. (2007), use individualistic representations of birds. Our model uses a projection of the presented area onto all possible flight angles. For this reason, multiple dimensions of turbine components and rotor speed for the particular type of turbine are used as input values to the risk model. Turbine specifications are as provided by the machine's manufacturer.

The modeled wind turbine consists of 2 fundamental components representing potentially different risks. We refer to these as the static and dynamic components (Fig. 2). The static areas of a turbine include all surfaces of the entire machine comprising a tower, which in current turbines is a simple taper with known base and top diameters; a rectangular nacelle housing the generator; a hemi-spherical hub; and rotor blades that taper in 2 planes. The dynamic component is the area swept by the leading edges of rotor blades during the time that a bird would take to pass through the rotor-swept zone.

Size and flight speed of birds.—For each taxon, the model requires values for the total length of the bird in flight, from bill tip to tip of the tail or outstretched legs, and the average speed of the species' flights. We obtained bird lengths either from museum specimens or from standard ornithological texts.

Accurate determinations of bird flight speeds can be complex and difficult to obtain (Videler 2005, Pennycuick 2008) and published data are not available for most species. However, published radar studies (e.g., Bruderer 1995, Bruderer and Boldt 2001) provide ranges of flight speeds for a variety of species, including congenerics with similar morphologies and ecological traits to a number of species we have assessed. Use of radar to collect bird flight data at the wind-farm site may provide flight speeds for species of interest. We consider that average ground speed (as opposed to air speed) is appropriate for modeling of multidirectional movements of birds.

Bird flight data.—The model requires data from the wind-farm site for the number of flights made by species of interest within a measured time and volume of airspace. Movement data may be obtained from fixed-time point counts using a methodology adapted from Reynolds et al. (1980), incorporating an effective detection range (Buckland et al. 1993). It may be collected by human observers or by using horizontal and vertical radar combined with call recording or visual species identification (e.g., Gauthreaux and Belser 2003, Desholm et al. 2006). Data represent the number of flights that birds make within a cylinder of airspace that is centered horizontally on the observer and the height of which is the maximum reached by rotor blades of the turbines. The data collection regime is designed with the aim of providing a representative sample of flight activity across the local range of diel, seasonal, and other environmental variables.

Model Modules

Probability of a single flight interacting with a turbine.—In some situations, such as during highly directional migratory passage, the presented area of turbines is determined from the angle of the birds' flight relative to the compass orientation of turbines. However, for the great majority of species (including temporary or permanent residents at an on-shore wind farm) this does not apply, and flights can be expected to approach turbines from any direction. For this situation, all dimensions of the turbine contribute to the area with which a flying bird might collide and the model uses a simple integration to determine a mean presented area. This represents a substantial advance over other collision risk models that depend on the assumption of a specific angle of approach as a bird encounters a turbine (e.g., Tucker 1996*a*, *b*; Bolker et al. 2006; Band et al. 2007).

We calculate the area presented by the static components of a turbine using a conservative assumption that none of them overlap or obscure any others. The area of each component is calculated individually, and these are then summed to determine a total static area for the turbine. Static areas are calculated from the simple length $\times$ width dimensions of all components visible by line of sight. These are then projected onto an arbitrary approach direction (effectively scaling by the cosine of the approach angle). For example, viewed directly from one side, only the side panel of the nacelle is visible. However, approached from 45° to the turbine, both the front and side panels are visible, and are thus scaled by $\cos(45)\varrho 1/\sqrt{2}$ to match that particular angle of view.

We calculate the dynamic area, swept during the movement of blades, from the dimensions of the stationary blades and the distance they travel at their average speed during the time taken by a bird to fly through the rotor-swept area. We assume that all flights involve forward movement, so the swept-area is derived from the length and speed of the particular species of bird, in combination with the thickness of the sweeping blade.

Each rotor blade is tapered in 2 planes. Thus the thickness of the blades, used to determine the time taken for a bird to cross through the swept area, is actually a function of the point in the rotor radius at which an individual bird's flight intersects the swept area. This presents a complication that we overcome by defining an effective blade, which is a simple rectangular cross-section that sweeps out precisely the same volume of space as the physical blade. In doing so, we calculate a constant thickness of blade that accounts for the fact that the thinner tips actually sweep far more space than the thicker base of the blade. This ensures also that our flux calculation is not compromised by introduction of a spatial variation at odds with other aspects of the model.

A further input parameter is the percentage of time per annum when rotors are not turning due to inappropriate wind speeds and routine turbine maintenance. Prior to commissioning of a wind farm, wind speed data are usually gathered and the expected percentage of downtime due to inappropriate wind speeds is determined. During downtime periods the rotor simply stops turning; and so risks associated with dynamic components only are reduced by this percentage of time, while all static components of the turbine remain as potential obstacles to flying birds.

Combining all presented areas of the turbine.—Modeling for multidirectional bird movements requires no dependence on approach angles nor on complexities of interactions between flight direction and wind direction. We thus reduce the turbine to its mean presented area. This is solved by the equation

$$\frac{1}{\pi}\int_0^{\pi} A(\theta)\,\mathrm{d}\theta$$

where A is the presented area of the turbine as a function of approach angle θ. We solve this numerically using a trapezoidal integrator (Press et al. 1992).

Probability of multiple flights interacting with a turbine.—Because counts of bird flights have been made across the wind-farm site and there is no obligatory relationship between point-count locations and particular sites proposed for turbines, we combine the data collected from all point counts. This provides a measure of flight activity, which is assumed to be constant across the site. Thus the field data reduce to a single ratio value for the subject species, which is the sum of all flights documented during all counts divided by the total time of observations. This equates to a maximum likelihood estimation of the mean of an assumed Poisson distribution.

To calculate a number of flights at risk of collision, we first reduce documented bird movements (M) to a measure of flux (F) using the equation

$$F = \frac{M}{T_{\mathrm{obs}} A_{\mathrm{obs}}}$$

where T_{obs} is the combined total time of all point counts and A_{obs} is the area of the vertical plane dissecting the observation cylinder. This flux is a measure of bird movements per time per square meter of vertical airspace. The third dimension, volume of airspace, is redundant (or tacit) due to the assumption that, unless involved in a collision, flight paths do not end arbitrarily in space.

We next multiply activity measure by the number of minutes in which the species is active during the 24-hour diel period, T, and the total presented area of the turbine, A. For year-round resident species, the "active minutes" are calculated for the entire year, while for seasonal or migratory species, they are calculated for the portion of the year that the species is present at the site. This then gives a measure of risk to the bird movements, $M_{\text{risk}} = \text{FTA}$.

Because the flight data are a measure of movements by the species in question and do not discriminate the number of individuals making the movements, the measure (M_{risk}) quantifies the total movements-at-risk for the species and does not reflect risk to individual birds.

To determine a risk rate from total of recorded movements-at-risk, it is necessary to extrapolate to a total number of expected bird movements per annum, M_{yearly}. We calculate this from the flight data, extrapolating the movements to a yearly total through the equation

$$M_{\text{yearly}} = M\frac{T_{\text{yearly}}}{T_{\text{obs}}}$$

We then deduce a probability of flights at risk of collision as $M_{\text{risk}}/M_{\text{yearly}}$. Note that T_{year} is the total time in a year, and not the diel activity period of the species, which has already been factored into the calculation of movements at risk.

The resultant value is now a probability of flights being at risk of collision with a single turbine. To this point, no account is taken of the bird's own ability to avert a collision. This is modified later through use of an avoidance factor.

Estimating number of turbines encountered per flight.—Every turbine is presumed to represent some risk for birds, so the total number of turbines proposed for the wind farm is an input to the model. Turbine layout of modern wind farms is primarily determined by the wind resource and turbines are micro-sited accordingly. Consequently, the machines are usually scattered on the landscape. Older wind farms had turbines arrayed in rows, and occasional modern facilities may be linear where they follow a single topographic feature.

To account for the number of turbines with which a single flight might interact, it would be necessary either to know precisely the route of every flight or to make informed assumptions about flight paths. The manner in which turbines are arrayed in the landscape is important to ascertain a typical number of turbines that a bird might encounter in a given flight. This number differs according to whether turbines are in a scattered array or a single row, and these require different calculations.

For a row of turbines, the likely number of encounters can be visualized by considering a row of N turbines in plan view and a flight path at angle Φ to the row. A flight directly along the line of turbines (Φ') will interact with all N turbines. As the angle of flight relative to the row increases toward 90°, flight paths have potential to interact with fewer turbines until an angle (Φ'') is reached at which the path has potential to interact with a maximum of one turbine.

For a single row of turbines, we define the piecewise smooth function, which gives the number of turbines for a given angle of crossing with,

$$n_{\text{interaction}} = \begin{cases} N, & \text{if } \theta \leq \phi' \\ \cot(\theta), & \text{if } \phi' < \theta \leq \phi'' \\ 1, & \text{if } \phi'' < \theta \leq \frac{\pi}{2} \end{cases}$$

This gives us an expected number of interactions as

$$\langle n_{\text{interaction}} \rangle = \frac{2}{\pi} \left[N \arctan\left(\frac{1}{N}\right) + \frac{\pi}{4} - \ln\left(\sqrt{2}\sin\left(\arctan\left(\frac{1}{N}\right)\right)\right)\right]$$

For scattered turbine arrays it is not realistic to assume that a bird will encounter all turbines in the wind farm in a given flight. We assume each flight has potential to cross between any 2 points on the outer edges of the farm. Given the size of most on-shore wind farms, this is a reasonable assumption for typical species of concern, such as raptors. When multiple flight paths are drawn randomly across the plan view of a wind farm, some paths may be circuitous and have potential to encounter many turbines, while others will pass through a small portion of the site and have potential to encounter relatively few turbines.

To deduce an average number of turbines likely to be encountered by any flight we use a topological, non-affine mapping technique. This spatial transformation can be illustrated as follows: if we were to throw a lasso around the perimeter of the site and shorten it to its minimum, we would find that all the turbines had collected in a circle. A straight flight path through this "lassoed" site is mathematically equivalent to a random walk across the unconstrained layout. The average of all flight paths crossing the center of this remapped farm will intersect with $\sqrt{N}$ turbines (where N is the total no. of turbines in the wind farm). This value is used in the model for the number of turbines that might be encountered per flight within a scattered turbine array.

For arrays that are neither entirely scattered nor linear, the model employs a simple weighted average of the values for fully scattered and entirely linear arrays.

Application of turbine avoidance capacity.—Birds have substantial ability to avoid obstacles; therefore, it is necessary to incorporate this capacity into the model. In common with other workers (Percival et al. 1999), we use "avoidance" in specific reference to behavior on the part of a bird that averts a potential collision with a turbine. The "avoidance rate" equates to the proportion of flights that might otherwise have involved interaction with a turbine but where the bird alters course and the flight does not result in a collision. For the purposes of the model it is of no consequence whether or not this is a result of a cognitive response by the bird to the presence of the turbine.

Turbine avoidance remains little-studied for any species, and empirical information about actual avoidance can be obtained for a given site only by studying the responses of birds in the presence of operational turbines (Chamberlain et al. 2006). One recent investigation has compared flight behaviors of 2 species of eagles in the presence of turbines at

2 operating wind farms with their behaviors at a site without turbines (Hull and Muir 2013).

Avoidance rate is incorporated into the model by scaling the movements at risk by $(1 - v)$, where v is a measure of the bird's ability to avoid objects. In this scenario, $v = 0$ corresponds to a blind, non-responsive projectile, and $v = 1$ represents a perfectly responsive bird able to avoid any object.

A novel feature of our model is its capacity to apply different avoidance values to the static and dynamic portions of a turbine. As noted by Martin (2011), birds are known to collide with both stationary and moving parts of turbines. This aspect of our model allows for differences in capacity of birds to detect and avoid the large, static components of modern turbines relative to their capacity to detect and avoid the small and fast-moving leading edges of rotor blades.

Size of population at risk.—When information about the size of the population at-risk is available, this can be factored directly into our model to provide results in the form of an expected number of individuals at risk of collision per annum. This is an important consideration because an input measured in terms of bird movements cannot provide an output in terms of individual birds. This aspect appears to have been largely overlooked by other workers, although Chamberlain et al. (2006) alluded to the use of a number of flights only, without incorporation of the number of individuals, as a potential issue in evaluation of collision estimates provided by the Band model (Band et al. 2007).

To deduce a predicted number of individual birds that are at risk of collision, a valid estimate is required of the number of individuals that may interact with turbines at the wind farm in the course of a year. If it is not feasible to obtain this for a species, then the output of the collision risk model will necessarily be the number of flights-at-risk per annum. Although this metric is not predictive of the number of individuals that might collide, it permits risk to be compared for various designs of a wind farm or between one facility and another. In rare cases, such as where there is a single migration passage through the site per annum, the number of movements may equate with the number of individual birds that are at risk. The great majority of risk modeling we have undertaken has been for raptors that are year-round residents. Due to their territoriality and relatively low densities, our studies at wind-farm sites have been able to ascertain the number of individuals using a site per annum, including both resident adults and juveniles, with a high level of confidence. For some other species, such as cranes (Gruidae), we have undertaken home-range studies to determine numbers present during the breeding season, and we have obtained local census data to estimate numbers of individuals that might encounter turbines during non-breeding seasons.

Given a population estimate, the number of flights at risk is attributed equally to the relevant number of individuals through the simple relation $M_{\text{individuals}} = \text{Yearly Movements/Population}$. We can then attribute individual mortality through

$$\text{mortality} = \text{Population}\left(1 - \frac{\text{Movements At Risk}}{\text{Yearly Movements}}\right)^{M_{\text{individuals}}}$$

MODEL VALIDATION

The model we describe here has been used to assess potential turbine collision risk for numerous species of birds for 23 commercial-scale wind farms proposed in Australia and one in Fiji. Eleven of these facilities have subsequently been built and are now operational. The model's projections have been used by regulatory authorities in determination of approval or modification to wind-farm designs for a range of species of concern. These include taxa as diverse as the orange-bellied parrot (*Neophema chrysogaster*), wedge-tailed eagle (*Aquila audax*), brolga (*Grus rubicunda*), and the large and readily observable Pacific fruit-bat (*Pteropus tonganus*) in Fiji.

The model's performance can be validated only when it can be compared with post-construction mortality data that are sufficient to permit calculation of an actual annual mortality rate and a 95% confidence interval for that rate. Conditions of regulatory approval for most wind farms that have been built to-date in Australia have varied considerably between state jurisdictions and over time. Generally they have not required rigorous investigation or public reporting of avian collisions that occur during operation. We have thus had limited opportunity to validate our model against empirical information for actual collisions. However, where these are available, we can compare the model's predicted average estimates with the measured confidence interval for actual mortalities to assess its predictive capacity. We present one such case study below.

Comparing the Model's Predictions With Empirical Data—A Case History

Substantial investigations have been undertaken at Bluff Point and Studland Bay wind farms in northwestern Tasmania entailing a number of studies of wedge-tailed eagle and white-bellied sea-eagle (*Haliaeetus leucogaster*). These have included utilization surveys designed to measure eagle activity before and after development of the wind farm; collision monitoring; eagle breeding success; eagle behaviors and movements relative to turbines and observers; and investigations and trials aimed at reduction of collisions (Hull et al. 2013). Commissioning of turbines began at Bluff Point Wind Farm in 2002 and at Studland Bay Wind Farm in 2007. Bluff Point Wind Farm consisted of 37 Vestas V66 turbines in a scattered array on an area of 1,524 ha. Studland Bay Wind Farm was situated 3 km south of Bluff Point and comprised 25 Vesta V90 turbines in a scattered array over an area of 1,410 ha. Both wind farms were close to the coast of northwestern Tasmania and resident white-bellied sea-eagles and Tasmanian subspecies of wedge-tailed eagle (*A. a. fleayi*) occurred at both sites.

Monitoring Eagle Flights

Movement data for both species were collected during point counts at Bluff Point Wind Farm site in 3 years prior to construction of turbines and in 4 years after they commenced operating. At Studland Bay, they were collected in 6 years prior to turbine construction and in 3 years after turbines commenced operation. As prescribed by regulatory authorities, point counts were undertaken in the austral autumn and spring. Ten replicate point counts were made in each season at 18 locations per wind farm. There were 545 point counts undertaken at Bluff Point between 1999 and 2007 and 854 point counts at Studland Bay between 1999 and 2009.

Collision Risk Model Results

We used the model to estimate risk based on movement data collected prior to construction for populations of 6 wedge-tailed eagles and 4 white-bellied sea-eagles at-risk per annum at each of the 2 wind farms.

State regulatory authorities have required that the collision risk model be re-run with the accumulated sum of eagle movement data obtained during the entire period of both pre-construction and operation of the 2 wind farms spanning the period from 1999 to 2009 (Table 1). We modeled static avoidance rate at 99% in all cases.

Documented Eagle Collisions

Carcass monitoring surveys were conducted at the Bluff Point and Studland Bay wind farms since they commenced operating. Fences to exclude mammalian scavengers were maintained at 27% of turbines across the 2 sites. All turbines, both fenced and unfenced, were searched routinely within a 100-m radius of the tower base. Search frequency was initially informed by trials to determine rates of loss to scavengers and of observers' capacity to detect carcasses. Since 2007, searches were carried out twice weekly during periods that may have represented higher risk to the species (i.e., eagle display period Jun–Aug, inclusive; and eagle fledging period mid-Dec–Feb, inclusive) and fortnightly outside these periods (Hull et al. 2013). Assessment of the extent of undetected eagle collisions (Hydro Tasmania 2012; Hull et al. 2013) concluded that it is unlikely that significant numbers of eagle carcasses were missed because they are conspicuous; the search zone around turbines was adequate to detect eagle carcasses where they will fall after colliding with turbines (Hull and Muir 2010); personnel on site had capacity to detect carcasses that may have been moved from the formal search zones; eagle carcasses in vegetation were found not to decompose readily and, even when scavenged, remains were identifiable; avian scavengers did not remove all evidence of carcasses and, although mammalian scavengers could remove carcasses, this was controlled at the subset of fenced turbines; survey intensity was informed by predetermined scavenger removal rates; and, although a small number of eagles survived collision with a turbine, in all documented cases such birds were unable to fly and are likely to have been detected because both scavenger exclusion and farm fences prevented them from leaving the site.

Table 1. Modeled mean annual turbine collision estimates for 2 eagle species based on movement data collected over the span of pre construction and operation of 2 wind farms in northwestern Tasmania, Australia, from 1999 to 2009. Estimates are shown for 4 potential dynamic avoidance rates. Static avoidance rate was modeled at 99% in all cases

	White bellied sea eagle		Wedge tailed eagle	
Dynamic avoidance rate (%)	Bluff Point	Studland Bay	Bluff Point	Studland Bay
90	0.9	0.8	2.7	1.9
95	0.5	0.4	1.5	1.1
98	0.2	0.2	0.7	0.5
99	0.1	0.1	0.4	0.3

Comparison of Collision Risk Model Estimates With Actual Mortality Rates

Given constraints of statistically low collision numbers, the model's estimates of annual collisions, based on the combined total of movement data from pre-construction and operation of the 2 wind farms from 1999 until 2009 (Table 1), compare well with actual mortality of the 2 eagle species at both wind farms (Table 2). The model's estimate of the number of wedge-tailed eagle collisions per annum at Bluff Point at a 95% avoidance rate was 1.5, which is the same as the mean number of documented mortalities per annum. Estimates provided for this case by model iterations for 90% and 95% avoidance rates fell within the 95% confidence interval of measured mortality rates. The model's estimates for number of collisions at a 95% avoidance rate for white-bellied sea-eagles at Bluff Point (0.5) and for wedge-tailed eagles at Studland Bay (1.1; Table 1) also closely approximated the mean numbers of documented mortalities per annum for the 2 species (0.4 and 1.0, respectively; Table 2). For those cases, the model's estimates for the range of avoidance rates between 90% and 99% fell within the 95% confidence interval of measured mortality rates. No white-bellied sea-eagle collisions have yet been reported from Studland Bay so, to date, the model's estimates are higher than actual experience for that species there.

MANAGEMENT IMPLICATIONS

We consider that there are 2 different, although not mutually exclusive, applications for modeling of bird collision risks at prospective wind farms. These are to provide projections of long-term effects of a particular wind-energy facility on key bird species; and to determine relative risks for key species that are associated with different wind-farm sites, different portions of large wind farms, and different types of turbines and/or turbine configurations.

In many respects, we consider the latter use of collision risk modeling is the most important contribution it offers. This application provides a tool for planning of wind farms to avoid, reduce, or mitigate potential risks to birds. The model we describe here has now been used in such an iterative manner for a number of prospective sites to evaluate relative risks to key species posed by different types, sizes, numbers, and layouts of turbines.

The integration in our model of data for numbers of bird flights with numbers of birds in the population at-risk is key to the accurate prediction of potential numbers of collisions. This aspect appears not to have been adequately considered previously but has real implications to the appropriate determination of actual risks posed by a wind farm. Our model's use of bird flight data to determine annual flux of movements; a mathematical solution to the typical number of turbines that might be encountered in a bird flight; capacity to assess wind-farm configurations ranging from turbines scattered in the landscape to linear rows of turbines; and the option of assigning different avoidance rates to components

Table 2. Average annual mortality rate and variance for 2 eagle species based on carcasses detected at 2 wind farms in northwestern Tasmania, Australia

	White bellied sea eagle		Wedge tailed eagle	
Wind farm	**Mean annual mortality**	**Annual variance (95% CI)**	**Mean annual mortality**	**Annual variance (95% CI)**
Bluff Point 2002 2012	0.4	0.1 1.0	1.5	0.8 2.6
Studland Bay 2007 2012	0.0	0.0 0.7	1.0	0.3 2.2

of turbines that pose more or less risk, all represent refinements designed to improve the predictive capacity of turbine collision risk modeling.

In the cases outlined here, where long-term mortality data sets have permitted validation of the model's collision estimates at given avoidance rates, the two have closely approximated each other. We will seek further opportunities to compare the results of our model with empirical mortality information from operating wind farms, with a view to wider application of the model.

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