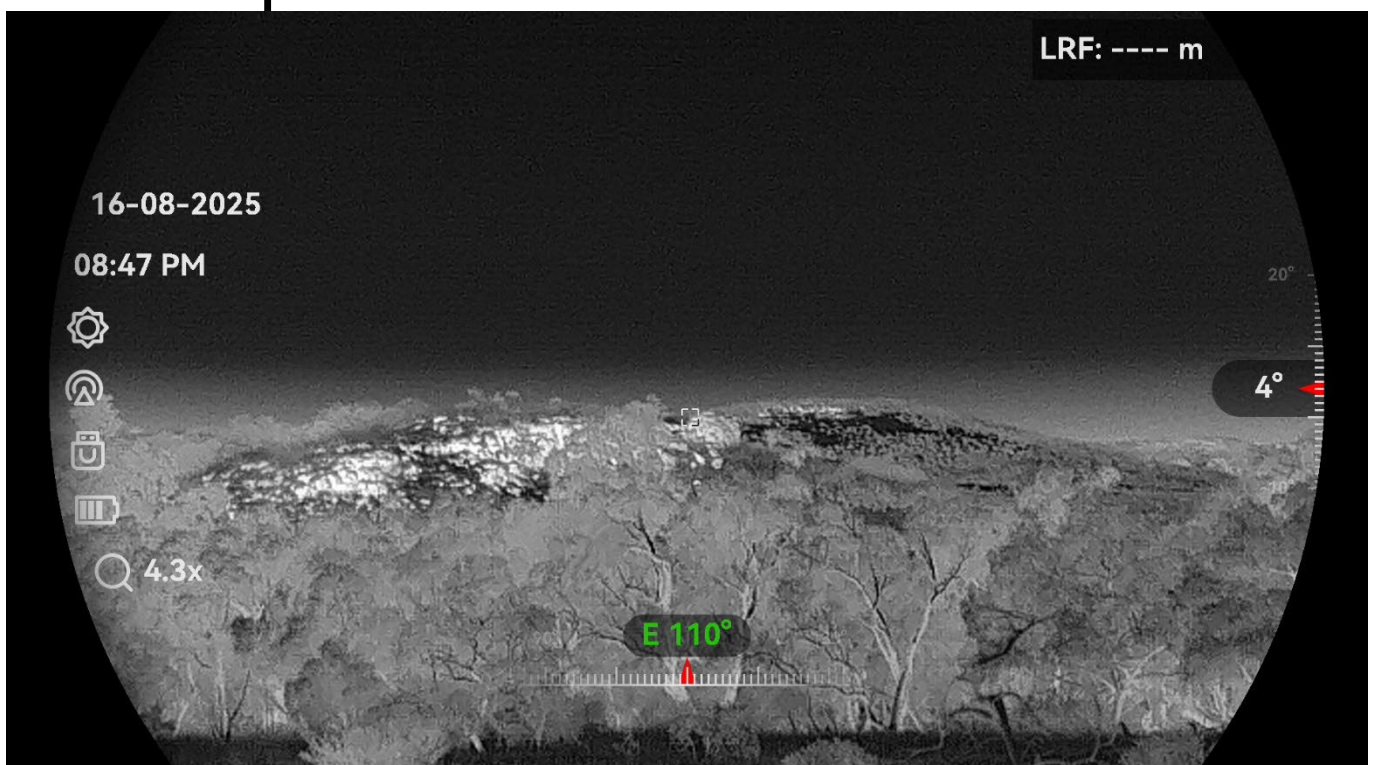


Bird and Bat Management Plan science for wind energy developments



Project 2.1.3 Literature review and bat traits analysis

Harry Butler Institute

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Table of Contents

Glossary and list of abbreviations.....	3
Acknowledgements	3
1 Executive summary.....	4
2 Key outcomes	4
3 Project background	5
3.1 Bat fatalities at wind turbines	5
3.2 Can we predict collision risk for bats?	6
3.3 Can we predict collision risk from bat traits?	7
3.3.1 Thaxter <i>et al.</i> (2017).....	8
3.3.2 Voigt et al. (2024).....	8
3.3.3 Reid and Baker (2025)	9
3.3.4 Specialised Zoological (2024).....	11
3.3.5 Other studies.....	11
3.4 Scope of this project.....	12
4 Methods	12
4.1 Study site description.....	12
4.2 Species profile for Pilbara bat species.....	13
4.3 Quantify temporal and spatial patterns of bat activity.....	13
5 Results	15
5.1 Species profile for Pilbara bat species.....	15
5.2 Pilbara leaf-nosed bat <i>Rhinonictoris aurantia</i> (Pilbara Form).....	17
5.3 Ghost bat <i>Macroderma gigas</i>	20
6 Discussion	21
7 References.....	22
8 Appendices	25
8.1 Literature review for the impact of wind turbines on wildlife.....	25
8.2 Appendix B. Specialised Zoological report 2024.....	26
8.3 Appendix C. Specialised Zoological report 2025	60
8.4 Appendix D. Records for other bat species.....	772

Glossary and list of abbreviations

Wind farm (WF)	Area of wind turbines under common management
Wind turbine (WT)	Individual wind turbine
BBSUS	Bird and Bat Site Utilisation Survey
IBRA	Interim Biogeographic Regionalisation for Australia
CRM	Collision Risk Modelling
Micrositing	Wind turbine micrositing is the detailed process of optimally placing turbines within a wind farm, balancing maximum energy capture with constraints like predicted risk for wildlife, terrain, wake effects (turbines blocking wind for others), noise, environmental rules, and property boundaries.

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1 Executive summary

A total of 10 echolocating bat species have been recorded at Bonney Downs to date. Two of these species are conservation significant (Ghost bat *Macroderma gigas* and Pilbara leaf-nosed bat *Rhinonictoris aurantia* (Pilbara Form)). A fruit bat species (Black flying-fox *Pteropus alecto*) has also been recorded from a single location at Bonney Downs (while flying foxes are recognised to have high risk to wind turbines, this species is not conservation significant). In this report we update on work carried out across two objectives:

- (1) **Develop a species profile for Pilbara bat species** to inform species-specific flight risk windows and to identify collision risk for species present at the proposed wind farm site at Bonney Downs in the Pilbara. Traits analysis has been used to predict potential collision risk for bats; here we report on three such analyses, including one international, one national, and one developed specifically for Bonney Downs. We have supported this review with analysis of available data on bat turbine collision mortalities, noting the geographic bias in records of wind farm fatalities records, with little or no evidence for some Pilbara bat species whose geographic range does not currently overlap with operational wind farms.
- (2) **Quantify space use by bats** – compare BBSUS data (surveys carried out four times a year over two years) to map species' presence across Bonney Downs and temporal (daily and seasonal) patterns of activity there. These data indicate spatial and temporal patterns of bat activity.

2 Key outcomes

- Available published data on bat mortalities at Australian wind farms represents species bias, as operational wind farms are principally in NSW and Victoria; consequently, there is no evidence of collision fatalities for 4 of the 10 microbat species recorded at Bonney Downs, as their geographic range does not currently overlap with operational wind farms. For example, there are no turbine collisions records for Pilbara Leaf-nosed Bat *Rhinonictoris aurantia* (Pilbara Form). Furthermore, while Ghost bat *Macroderma gigas* range does overlap with wind farms in northern Queensland, there are also no available records of collision fatalities.
- We reviewed four traits-based protocols for predicting bat wind turbine collisions, and compared these with the predictions for the 10 bat species present at Bonney Downs. The fatality threat categories provided in their international review by Voigt *et al.* (2024) are generally most conservative (8/10 species classed as having 'HIGH' risk of turbine collision). In their Australia-wide categorisation, Reid and Baker (2025) classed four species as having 'HIGH' risk of turbine collision, while Specialised Zoological (2025) identified only two species as having 'HIGH' risk of turbine collision for their categorisation tailored specifically to Bonney Downs.
- Pilbara Leaf-nose bat *Rhinonictoris aurantia* (Pilbara form) is categorised as LOW risk of wind turbine collision based on its foraging style (unlikely to fly higher than 50 m) and small number of records at Bonney Downs (Specialised Zoological 2024, 2025). Reid and Baker (2025) classed the species as HIGH overall impact of wind turbines, largely due to scores attributed to the species' habitat specialisation and population status (VU).
- Ghost bat *Macroderma gigas* is classed as having LOW collision risk but HIGH overall impact of wind turbines, largely due to scores attributed to the species' habitat specialisation and population status (VU) (Reid and Baker 2025). The species is recognised as having MEDIUM risk of flying higher than 50 m (Specialised Zoological 2024), but the species has only been recorded at Bonney Downs once (Specialised Zoological 2025 did not list a collision categorisation for this species).
- Analysis of the timing of BBSUS bat records suggest that no suitable roost caves for Pilbara Leaf-nose bat *Rhinonictoris aurantia* (Pilbara form) or Ghost bat *Macroderma gigas* are present at Bonney Downs, whilst bat species that make use of tree roosts within the Bonney Downs project area are present from the first hours of dark.

3 Project background

Fortescue Ltd. (Fortescue) has set the ambitious industry-leading target to be carbon neutral by 2030. To reach this commitment to decarbonise its Pilbara mining operations, they are seeking wind and solar energy developments to eliminate fossil fuel use from iron-ore operations. Fortescue is investigating options for wind and solar energy developments lying within the Chichester IBRA subregion of the Pilbara IBRA region.

Collision risk models (CRM) are commonly used to estimate the impact of windfarm projects on bird species. These models are typically developed using site utilisation studies to determine which species occur in a project area, what heights they fly at and what habitats were utilised. Similar analysis has not been easily carried out for bat species, with modelling for bats generally only applied to habitat suitability assessments (e.g., Forcey *et al.* 2012, Korner-Nievergelt *et al.* 2013, Ferreira *et al.* 2015). A common limitation across previously completed CRMs is the lack of available observational data collected for bat species (i.e. flight height) due to difficulties associated with nocturnal observational studies. To address this limitation, species profiles have been typically developed, based on species' known ecology, to identify potential risks for each bat species.

This project represents a collaboration between the Harry Butler Institute (HBI) at Murdoch University and Fortescue for identifying potential collision impacts at Bonney Downs Station by bats, as per the Onshore Wind Farm Guidance (DAWE 2021, DCCEEW 2023, 2024). This work recognises the need to identify potential unintended impacts that will undermine both climate and biodiversity goals, and to apply these from the earliest planning stages, in alignment with Fortescue's Biodiversity Strategy (2023).

3.1 Bat fatalities at wind turbines

Bat fatalities at wind power facilities can be very high, representing the greatest source of bat mortality from any anthropogenic cause (Cryan & Barclay 2009). Bat mortality is highly variable and highly localised to different regions (Forcey *et al.* 2012). Estimates of fatalities/MW/year, or fatalities/turbine/year, have been published globally (Lentini *et al.* 2025b), and demonstrate that estimates vary markedly across studies, likely reflecting local ecology and species distributions (Lentini *et al.* 2025b). For example, while some estimates for wind power facilities in the eastern USA are as high as 20 to 70 bats/turbine/year, especially at forested ridge tops (Kunz *et al.* 2007), estimates for the central USA are more modest, ranging from 0.1 to 7.8 bats killed/turbine/year at wind energy facilities in Minnesota, Wisconsin, and Iowa (Arnett *et al.* 2008).

In the USA, Bat Conservation International has identified 3 bat species to be at risk of extinction due to impacts of wind turbines, with a predicted 50% decline for populations of these species over the next decades. Migratory tree-roosting species account for nearly 80% of bat fatalities at wind farms (WF) across the USA and Canada, with Hoary bats (*Lasiurus cinereus*), Eastern red bats (*Lasiurus borealis*), and Silver-haired bats (*Lasionycteris noctivagans*) most often reported (MacLaurin *et al.* 2022). The Hoary bat is the species most frequently killed by turbines in North America and it is predicted that the Hoary bat population could decline by as much as 90% over the next 50 years, drastically increasing the risk of extinction (Frick *et al.* 2017).

In Australia, the average for Victorian wind farms is 11.4 [10.0–13.0] bats killed/turbine/year (data for 1137 turbines across 23 wind farms), representing 13 bat species; these values are almost twice as high as fatalities for birds (Lentini *et al.* 2025a).

3.2 Can we predict collision risk for bats?

Predictive collision risk modelling can provide a basis for decision-making regarding approvals, mitigation, and micro-siting prior to construction of the wind facility. Understanding the reliability and validity of CRMs is vital, to select between options. A literature review of collision risk modelling for wildlife was carried out with results presented in **Appendix A**.

Some turbines kill more bats than others, with the position of turbines (i.e. proximity to suitable foraging resources, roosts or flight pathways) likely a bigger cause of fatalities than turbine height or blade length (Lentini *et al.* 2025a). Some of the earliest predictions of bat fatalities have consequently been based on habitat assessment. For example, Forcey *et al.* (2012) created a landscape-level collision risk tool to quickly screen for large-scale siting decisions (more for wind farm site selection rather than micro-siting individual wind turbines) based on habitat, identifying the habitat selection for different bat species. For example, they identified that large tracts of forest and river corridors were favoured by Eastern red bats and were the sites of most collision risk. Predicted collision risk for Silver-haired bat and Hoary bat were nearly identical, and driven largely by forest and river corridors as well as locations with warmer temperatures and lower average wind speeds. They compared the collision predictions for these three bat species against mortality monitoring and showed strong correlations with observed mortality ($r=0.85$, 0.90 , and 0.91 for Eastern red, Silver-haired, and Hoary bats respectively).

Understanding habitat use by bat species through acoustic analysis of bat activity can therefore inform decisions regarding wind turbine placement. However, other studies report that pre-construction acoustic surveys are poorly correlated with post-construction collision fatalities (Ferrer *et al.* 2012, e.g., Hull & Cawthen 2013, Lintott *et al.* 2016). This may be due to a number of reasons:

- First, technical issues may reduce the representativeness of pre-construction surveys:
 - The size of the area surveyed by acoustic monitoring is generally very small, and can be restricted by accessibility. Such surveys therefore may not capture the range of habitats (e.g. open air) that can be occupied by bat species.
 - Acoustic recorders are generally mounted at ground level for pre-construction surveys, and therefore do not represent use of the airspace at RSA height, especially for high-flying bats, or species with low detectability (Hull & Cawthen 2013).
- Second, there is evidence for change in species composition of bats because different species either avoid or are attracted to wind turbines:
 - Video evidence indicates that the flight paths of bats are influenced by the presence of wind turbines (Cryan *et al.* 2014) and their collision with turbines is more likely to be due to attraction to the turbines rather than random or coincidental collision paths (Cryan & Barclay 2009). Wind turbines seem to reach high enough into the airspace to interfere with the migratory movements of insects (Rydell *et al.* 2010). In Europe and North America, bats found dead at wind turbines belong almost exclusively (98% and 75% on the two continents, respectively) to aerial-hawking species that typically feed in the open air or at least several metres away from surfaces of vegetation (Cryan & Barclay 2009, Rydell *et al.* 2010). In addition, bats have been observed foraging near turbines and those found dead beneath them have full stomachs (e.g. Reimer *et al.* 2010), highlighting the likelihood that bats are vulnerable to blade-strike when they are feeding around the turbines.
 - In contrast with the above, there have been multiple studies reporting that some bats avoid wind turbines (e.g., Barré *et al.* 2018, Reusch *et al.* 2023). To understand the mechanism behind such avoidance, Ellerbrok *et al.* (2022) carried out acoustic surveys at ground and canopy height (80, 130, 250 and 450 m from 25 wind turbines). Results showed that narrow-space-foraging bats (i.e. forest specialist bats such as the Greater mouse-eared bat) avoid turbines, but there was no difference for edge or aerial (open) foragers. As a general pattern, narrow-space-foraging bats are least likely to encounter wind turbines as they avoid the habitat disturbance and clearing that accompanies a

wind farm development, while high and fast-flying migrants are most at risk of wind turbine collision (Michael Whitby, 2025 Pers comm. ELIANZ seminar).

Species-specific foraging behaviour, or the background landscape, influences bat space use and therefore likelihood of encountering a wind turbine. Smallwood and Bell (2020, page 2) note that *"predicting bat fatality rates has not been successful, neither from pre-construction surveys nor post-construction surveys concurrent with fatality monitoring"*. Predicting collision risk for bats from pre-construction acoustic surveys does not account for changes in bat behaviour post-construction. Furthermore, because some bat species avoid wind turbines while others are attracted to potential foraging opportunities, extrapolating wind turbine collision predictions from one study site to another is problematic due to differences in bat species composition.

3.3 Can we predict collision risk from bat traits?

Functional morphology traits of bats are likely to be the best predictor of their vulnerability to turbine strike. A range of traits have been used to infer where bat species are likely to forage, and therefore their likely turbine collision risk. These traits are broadly reflective of bat ecology, and therefore have been used to predict how bats fly around wind turbines.

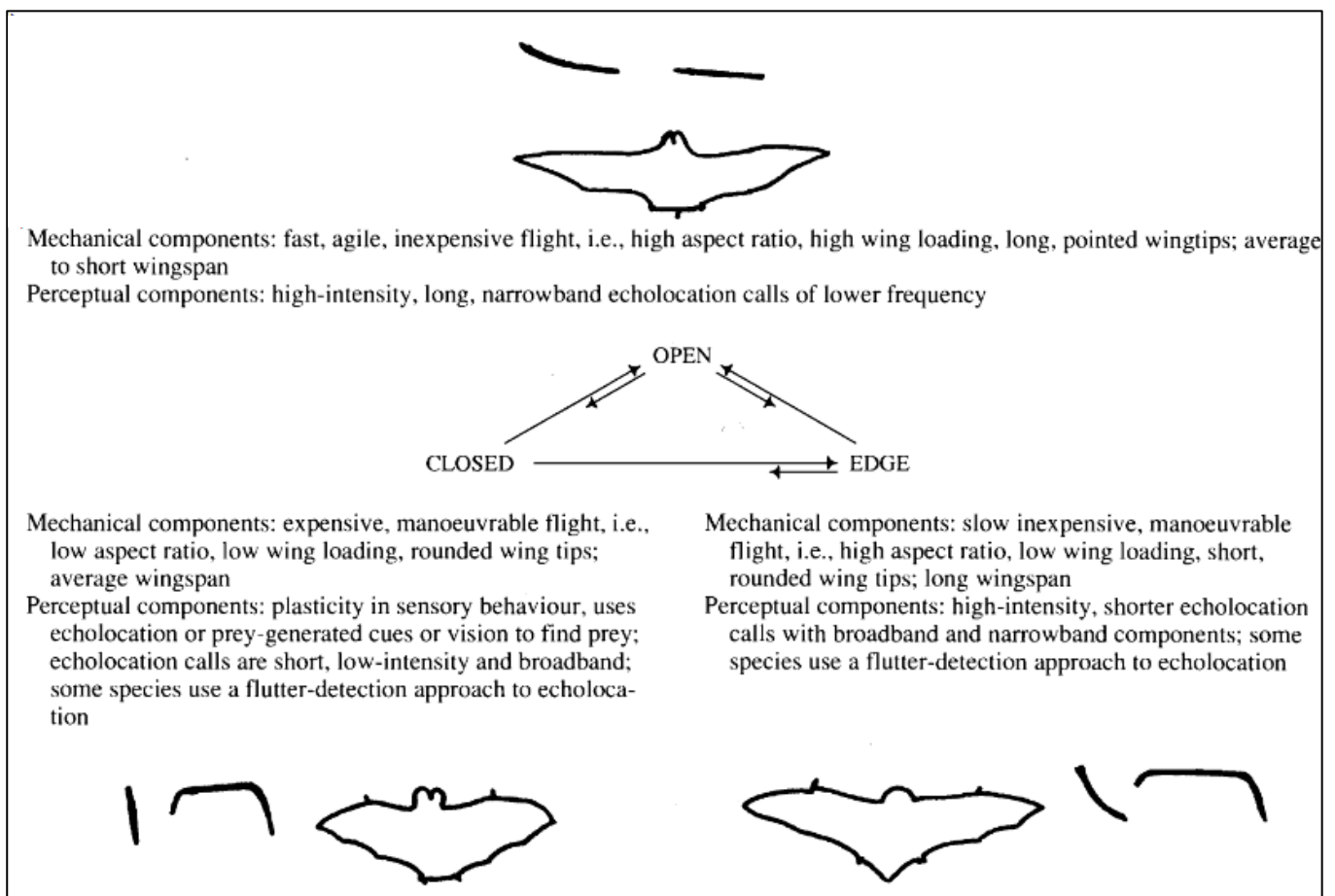


Figure 1. Link between wing morphology and perceptual characteristics that have been linked with where bats forage (in open, edge or closed habitats). The length of the arrows represents the degree of flexibility potentially exhibited by bats with the mechanical and perceptual properties shown. The bat silhouettes are based on information in Norberg and Rayner (1987) and the echolocation call features are depicted as sonograms. Image sourced from (Fenton 1990).

Wing loading provides an indication of a bat species' flight manoeuvrability and therefore whether it typically forages within cluttered vegetation or in open airspace (hereafter 'foraging class'). Species with low wing loading tend to be more agile and capable of slow, highly manoeuvrable flight suited to cluttered habitats, whereas species with higher wing loading are adapted for faster, more energy-efficient flight in open environments (Norberg & Rayner 1987).

Similarly, echolocation call frequency reflects the environments in which bats typically forage. High-frequency, short-range calls are advantageous in cluttered habitats because they provide fine-scale spatial resolution, while lower-frequency, longer-range calls are favoured in open spaces where bats need to detect prey over greater distances (Fenton 1990, Schnitzler & Kalko 2001).

3.3.1 Thaxter *et al.* (2017)

In the first analysis comparing bat traits with wind turbine fatalities, Thaxter *et al.* (2017) carried out a meta-analysis comparing bat traits (body mass, no. litters, roost type [tree or other], dispersal distance [could not be separated from migration due to knowledge gaps], and hibernation [yes/no]; data extracted from the PanTHERIA database) with recorded collision mortalities. They reported that long dispersal distances of migratory species were the best predictor of fatality rates in bats, but this may be because some of the most well-studied areas align with major migration routes (e.g., Germany, Voigt *et al.* 2015, Altamont Pass Wind Resource Area, Smallwood & Bell 2020); other studies report that resident species are most common turbine fatalities in South Africa (review of 59 wind farm studies by Aronson 2022, where *Tadarida aegyptiaca* Molossidae made up 53% of all carcasses) and Mexico (5-year study at a single wind farm, Bolívar-Cimé *et al.* 2016). Thaxter *et al.* (2017) reported that the other traits included in their analysis were not significantly correlated with turbine fatalities. It is notable that these authors did not include flight traits (wing loading, wing aspect ratio, or echolocation characteristics) that would indicate where bats would likely be foraging and therefore predict likely flight heights.

3.3.2 Voigt *et al.* (2024)

Using habitat and foraging style, Voigt *et al.* (2024) identified general patterns of threat represented by wind turbines for bat taxa: (1) fatalities, (2) habitat loss and (3) displacement, with evidence from the literature for different bat taxa.

Table 1. Potential impacts of wind turbines on bats shown by taxonomic group and functional guild (Voigt et al. 2024, Table 1 on page 243).

Taxon	Functional guild		Threat		
	Habitat	Foraging style, example taxa	Fatalities	Habitat loss	Displacement
Yangochiroptera	Open space	Aerial insectivores, e.g., some Vespertilionidae, all Molossidae, some Mormoopidae and Emballonuridae	High ^{c-i, l, m, r, u-y, ab, ac, ad}	Medium ⁿ	High ^{n, o, s, t, z, aa, ae}
	Edge space	Aerial insectivores, e.g., some Vespertilionidae, some Emballonuridae	High ^{j, l, m, v-y, ac, ad}	Unknown	High ^{f, z, aa}
	Edge space	Trawling, e.g., some Vespertilionidae, Noctilionidae	Low to medium ^{c, w, ad}	Low risk	Unknown
	Narrow space	Active gleaning, e.g., some Phyllostomidae	Low to medium risk ^{a, x, y, ab, ad}	High risk	Unknown
	Narrow space	Passive gleaning, e.g., some Vespertilionidae, Nycteridae	Low risk ^{c-i, l, m, x, ac}	High risk	High risk ^{p, q, r, t, z, aa, ae, af}
Yimpterochiroptera	Open and edge space	Fruit-eating pteropodids	High risk ^{ac}	Low to medium risk	Unknown
	Edge and narrow space	Nectar-feeding pteropodids	Unknown	High risk	Unknown
	Edge space	Aerial insectivores, i.e., Craseonycteridae	Unknown	Unknown	Unknown
	Narrow space	Flutter-detecting bats, e.g., Rhinolophidae	Low risk ^{a, b, c}	Unknown	Unknown
	Narrow space	Active gleaning, i.e., Megadermatidae	Low risk	Unknown	Unknown

Note: Echolocating bat species were assigned to functional groups according to Denzinger and Schnitzler (2013). Threat assignments are based on a literature search. Notably, potential impacts of wind turbines may vary among species within functional guilds. Threat assessments are shown in italics when inferred from the general biology of bats; for example, forest-dependent bats were considered to suffer from habitat loss because of the logging involved when turbines are constructed in forests. The taxonomic division of Yangochiroptera and Yimpterochiroptera follows Teeling et al. 2005. ^aLikely high risk when wind turbines are placed next to large colonies (e.g., cave-roosting species). ^bLikely higher risk when wind turbines are placed at commuting routes for some large species (e.g., *Hipposideros armiger*) that usually fly above canopy during commuting. Sources: ^cRydell et al. (2010). ^dRodrigues et al. 2015. ^eVoigt et al. 2015. ^fArnett and Baerwald 2013. ^gArnett et al. 2008. ^hBaerwald et al. 2014. ⁱHein et al. 2013. ^jKruszynski et al. 2022. ^kLehnert et al. 2014. ^lMăntoiu et al. 2020. ^mRoemer et al. 2017. ⁿReusch et al. 2022. ^oReusch et al. 2023. ^pEllerbrok et al. 2022. ^qEllerbrok et al. 2024. ^rCryan et al. 2014. ^sMillon et al. 2018. ^tGaultier et al. 2023. ^uRoeleke et al. 2016. ^vVoigt et al. 2012. ^wVoigt et al. 2022b. ^xCabrera-Cruz et al. 2020. ^yRodríguez-Durán and Feliciano-Robles 2015. ^zLeroux et al. 2022. ^{aa}Barré et al. 2018. ^{ab}Barros et al. 2019. ^{ac}Aronson 2022. ^{ad}Agudelo et al. 2021. ^{ae}Barré et al. 2018. ^{af}Mckay et al. 2023.

3.3.3 Reid and Baker (2025)

Reid and Baker (2025) recently published collision threat predictions for Australian birds and bats. For bat species, their predicted susceptibility risk score:

$$\text{Susceptibility (S)} = (\text{Flight Height} * 2 + \text{Flight Manoeuvrability} + \text{Habitat Specialisation} * 0.5) / 3 \quad (\text{eq. 1})$$

Susceptibility was calculated based on three parameters:

- (1) **flight height** is recognised as an important factor influencing bat fatalities (e.g., Baerwald & Barclay 2009), although there is next to no data on Australian bat species, and much of the information on bat flight heights relies on personal opinion. In their scoring, Reid and Baker (2025) categorised as below, within or above rotor swept area (RSA), assuming a RSA between 30–275 m¹) (**Figure 2**):

¹ Noting that the wind turbines proposed for Bonney Downs will have a rotor swept area of ~100–300 m, and therefore greater ground clearance than accounted for by these authors.

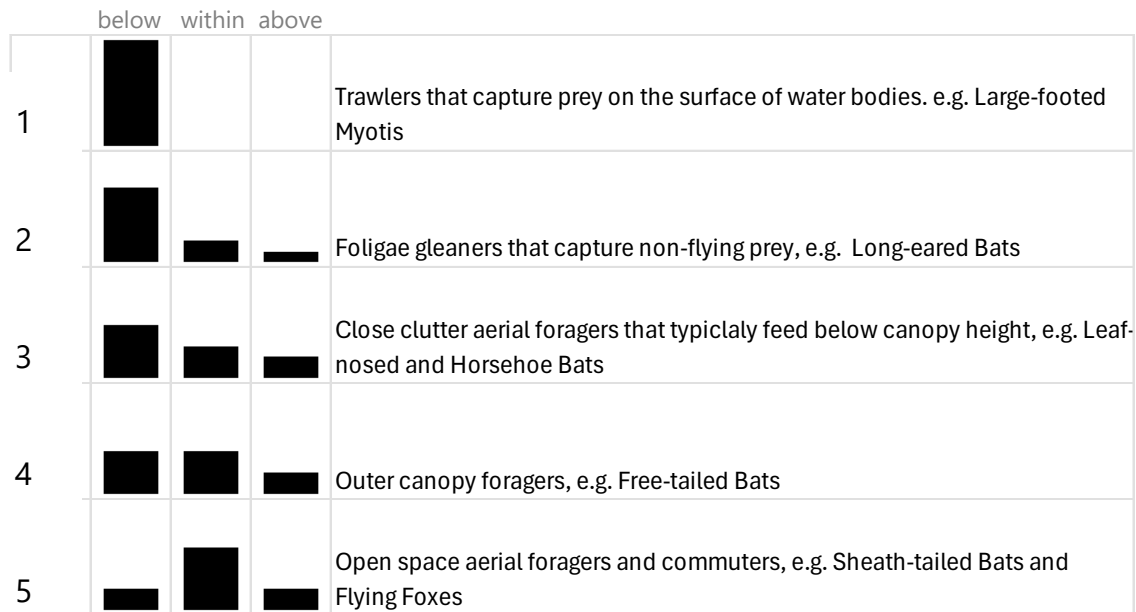


Figure 2. Flight height grouping for Australian bats given by Reid and Baker (2025). The relative height of the bars is illustrative of the relative amount of time that bats in this trait group are expected to fly below, within and above collision risk height (i.e., within the area encompassed by the rotating blades). Source Reid and Baker (2025).

- (2) **flight manoeuvrability** was based on a wing loading index ($FM^{bats} = \text{body mass/forearm length}$; data from Thomson et al. 2024). The assumption being that species with low relative wing loading ratio would have lower potential risk to direct wind turbine interactions because this characteristic predicts flight in cluttered habitats as opposed to species such as flying foxes that have a higher wing loading and undertake longer flights in open areas (Table 2). However, the authors did not include wing shape in their analysis – clutter foraging bats have broader wings and are more manoeuvrable, while open-foraging bats have narrow wings (Fenton 1990).

Table 2. Allocation of Flight Morphology scores for bats.

Flight Manoeuvrability (FM) value	Flight Manoeuvrability score
< 0.23	1
>=0.23 and < 0.49	2
>= 0.49 and < 1.24	3
>= 1.24 and <= 2.37	4
> 2.37	5

- (3) **habitat specialisation** is a measure of discrete feeding habitat types (where low scores indicate generalist species that use a range of foraging habitats and high scores reflect habitat specialists), as a potential impact metric of habitat displacement based on literature review and subsequent refinement in the expert workshops (Table 3). For bats, the habitat utilisation was compiled from available information, Reid and Baker (2025) cite: (Menkhorst & Knight 2001, Churchill 2008b, Reardon et al. 2014, Woinarski et al. 2014, Parnaby et al. 2021) with subsequent refinement in the expert workshops.

Table 3. Allocation of Habitat Specialisation scores.

Habitat Specialisation (HA) value	Habitat Specialisation score
>=9	1
6, 7 or 8,	2
4 or 5	3
2 or 3	4
1	5

For 81 Australian bat taxa, using these calculations, Reid and Baker (2025) list 20 species with a score >4.74, which they classed as HIGH risk due to wind turbines, 44 with a score between 3.95–4.74 classed as MEDIUM risk, and 17 species with scores <3.95 classed as LOW risk.

3.3.4 Specialised Zoological (2024)

Specialised Zoological (2024; **Appendix B**) provided a categorisation of how likely bat species present at Bonney Downs would be to fly >50 m altitude² as an authoritative estimate based on Kyle Armstrong’s accumulated field observations. In 2025, ‘probability’ of presence (Frequency of Detection values, as quartiles of detection probabilities calculated across all Bird and Bat Site Utilisation Survey (BBSUS) sites surveyed in 2023–2025) was added to create a matrix of likelihood x flight height category, with each bat species attributed a risk score that was later categorised into low, medium and high collision risk (Specialised Zoological 2025; **Appendix C**).

3.3.5 Other studies

The study by **Morant et al. (2025)** further supported the importance of foraging class as an ecological predictor of turbine fatalities in bats. Morant et al. (2025) compared turbine fatalities for 19 bat species across peninsula Spain. They found no correlation with morphological traits (forearm length, wing loading index, aspect ratio index and body mass) or maximum seasonal movement, and maximum foraging distance, but strongest prediction for foraging style (narrow, edge or open foraging guilds according to echolocation behaviour). Aerial insectivores, particularly the functional guilds of open-space and edge-space foraging bats which forage and commute at the level of the turbine blades were most at risk of collision (e.g., *Pipistrellus pipistrellus/pygmaeus*, *Tadarida teniotis*, *Nyctalus* sp., *Miniopterus schreibersii* and *Eptesicus* sp.).

In some cases, however, morphology alone can be insufficient to predict turbine fatalities. **Crane et al. (2025)** developed a risk assessment for Southeast Asian bat species, predicting that species with both low relative wing loading and wing aspect ratio (reflecting relatively slow flight in cluttered habitats) would have lower potential risk to direct wind turbine fatality. Their model correctly predicted probability for 10 known fatality species, but a simple model (not phylogenetically corrected due to missing phylogeny data for many species) with pseudoabsences (drawn from all regions with a wind turbine facility monitoring fatalities) did not accurately predict known fatality species for Southeast Asia. Tests of model fit suggested that that relevant variables may be missing from their model. This study indicates important remaining knowledge gaps for predicting turbine collision for all bat species, especially rare species and those whose geographic ranges do not overlap with operational wind turbines, and highlights species-specific parameters that can influence their behaviour and therefore collision risk.

² Noting that the wind turbines proposed for Bonney Downs will have a rotor swept area of ~100–300 m, and therefore greater ground clearance than accounted for by these authors.

3.4 Scope of this project

The aims of the work were to identify traits of Pilbara bat species and analyse potential environmental predictors of their activity, including time of night, wind speed and flight height. This report focusses on the two conservation-significant bat species and the remaining species are presented in **Appendix D**. This project describes analysis of acoustic data (using autonomous recording units (ARU)) to address two key objectives:

- (1) **Develop a species profile for Pilbara bat species** to inform species-specific flight risk windows and to identify collision risk for species present at the proposed wind farm site at Bonney Downs in the Pilbara.
- (2) **Quantify space use by bats** – compare BBSUS data (surveys carried out 4 times a year over 2 years) to map species' presence across Bonney Downs and temporal (daily and seasonal) patterns of activity.

4 Methods

4.1 Study site description

Bonney Downs Station is a pastoral lease that operates as a cattle station in Western Australia. It is located approximately 115 km south of Marble Bar and 130 km north of Newman on the Nullagine River in the Pilbara region of Western Australia. A 144 m-tall Meteorological mast ('met mast') was established and has been collecting wind speed, wind direction, temperature, and air pressure metrics since 20 October 2023. Wind speed at Bonney Downs shows a daily pattern of increasing in the afternoon/early evening, and blowing relatively consistently overnight until the morning (**Figure 3**).

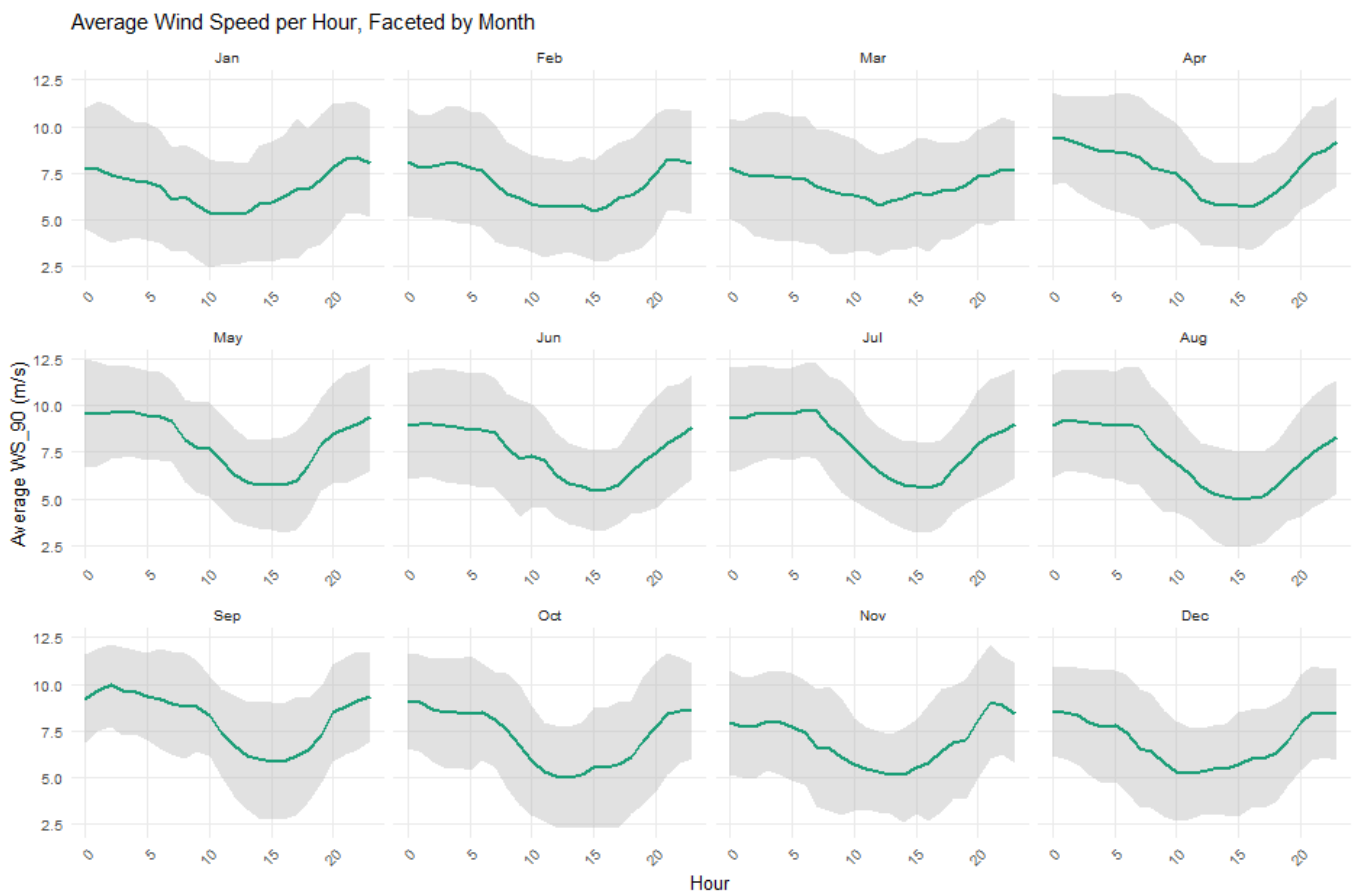


Figure 3. Wind speed measured from the met mast at 90 m height. Values show the means and 95%CI.

4.2 Species profile for Pilbara bat species

We reviewed Atlas of Living Australia records for the Pilbara (ALA Pilbara IBRA area; data downloaded 26 February 2025) and distribution information in a curated source of distribution records maintained by the Australasian Bat Society, Inc. (<https://www.ausbats.org.au/batmap.html>) (Milne *et al.* 2023). We collated information on the traits of bats, including morphology, call parameters, and published data for wind turbine mortalities. We included records of each bat species across the Pilbara IBRA, and summarised records for BBSUS (see next section).

We have reviewed four categorisation systems for predicting turbine collision risk in bats, including two developed specifically for Australian species (Thaxter *et al.* 2017, Specialised Zoological 2024, Voigt *et al.* 2024, Reid & Baker 2025, Specialised Zoological 2025). We have included risk assessments for the bat species present at Bonney Downs using three of these systems (Specialised Zoological 2024, Voigt *et al.* 2024, Reid & Baker 2025, Specialised Zoological 2025).

4.3 Quantify temporal and spatial patterns of bat activity

BBSUS records. SM4 Bat recorders were deployed to determine the bat fauna assemblage of the Bonney Downs project over eight BBSUS (Ecologia 2025). Acoustic data collected during the BBSUS were analysed with detections determined from manually verified and automatically classified recordings collected from May to September 2025. Acoustic recordings were identified to species using Kaleidoscope Pro software, with a library of calls identified to species against the Specialised Zoological Year 1 report for Bonney Downs (Specialised Zoological 2024) and the Field Guide to Australian Bats (**Figure 4**). Activity counts were completed by allocating every data file (each 2 - seconds duration) to a species, and then counting the number of call records for each species.

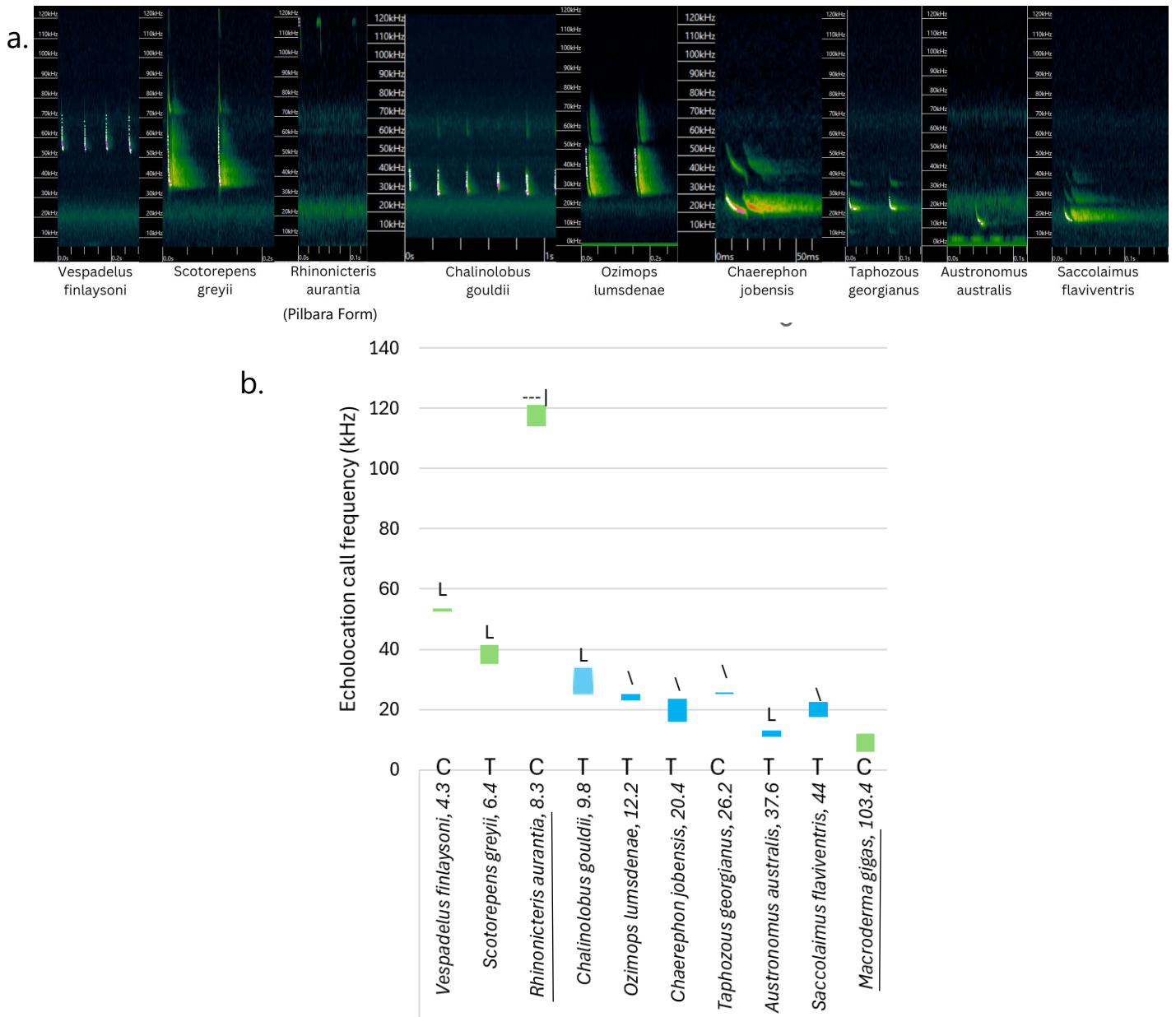


Figure 4. (a) Species call sequences identified from acoustic data collected by Murdoch University at Bonney Downs at sites 35 and 36 between May 2025 to November 2025. (b) Characteristic echolocation frequency of bat species that have been recorded to date at Bonney Downs. Bars show the range of call frequency. Colours represent foraging class: green = clutter and blue = open. Species are sorted left to right by increasing body mass, with *n*(Specialised Zoological 2024)umbers under the x-axis referring to the average body mass of each species. C=cave roosting, T=tree roosting species. Note that Ghost bats have not been recorded as part of the auditory surveys at Bonney Downs, but they have been detected using acoustic lures. The two conservation significant species underlined in (b). Frequency modulated calls have a steep diagonal line or sharp 'I', where the frequency rapidly changes (sweeps) up or down over a short time, and is best suited for determining distance and fine details, as the broad frequency range provides high resolution. --- Constant Frequency (CF) calls have a flat, horizontal shape with a single, unchanging frequency, that is best suited to detecting movement via the Doppler shift (pitch change) and identifying stationary objects.

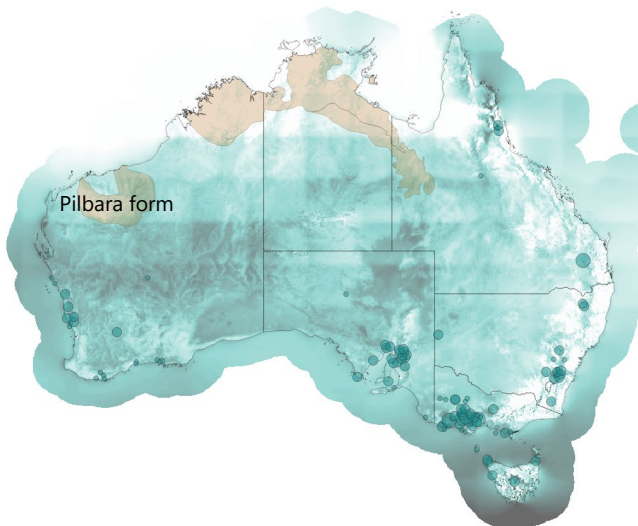
5 Results

5.1 Species profile for Pilbara bat species

A total of 18 bat species are known to occur in the Pilbara bioregion (ALA Pilbara IBRA area; data downloaded 26 February 2025). Of these, 10 microbat species have been recorded to date through ARU deployment at Bonney Downs (**Table 4; Figure 4**). The body mass of the recorded bat species ranges from 4 to 103 g (**Appendix B**). A single fruit bat species (Black flying-fox *Pteropus alecto*) has also been recorded from a single location at Bonney Downs. While flying foxes are recognised to have high risk to wind turbines, this species is not conservation significant, and no significant population occurs at the study site.

Available published data on bat mortalities at wind farms represents bat species bias, as operational wind farms are principally in NSW and Victoria (Ecogeneration 2023). Consequently, there are no available data of collision fatalities for 4 of the 10 microbat species recorded at Bonney Downs, as their geographic range does not currently overlap with operational wind farms (**Figure B1**). For example, there are no turbine collisions records for the entire species' range of *Rhinonictis aurantia*, and while the range of the Ghost bat *Macroderma gigas* does overlap with wind farms in northern Queensland, there are no available records of collision fatalities for this species (**Figure 5**).

a. Pilbara Leaf-nosed Bat *Rhinonictis aurantia* (15 ALA records; **VU**) **LOW**[§]



b. Ghost Bat *Macroderma gigas* (104 ALA records; **VU**) **MEDIUM**[§]



Figure 5. Overlap between species distribution maps (BatMap 2021, Milne et al. 2023), wind resources (green colour gradient) (Global Wind Atlas 2025) and operational wind farms (green circles; relative sizes reflect energy generation capacity) (Ecogeneration 2023) for 2 conservation-significant bat species recorded at Bonney Downs in the Pilbara. The numbers of ALA records are indicated. [§] Estimated risk scores for each bat species recorded in the 2023-2024 surveys at Bonney Downs, based on an authoritative estimate of which species are likely to be flying at >50 m in altitude (Specialised Zoological 2024, 2025). (a) Range of the Pilbara form is indicated.

The 'fatality' threat categories provided in their international review by Voigt et al. (2024) are generally very conservative (8/10 species classified as having 'HIGH' risk of turbine collision) (**Table 4**). In their Australia-wide categorisation, Reid and Baker (2025) classified four species as having 'HIGH' risk of turbine collision, while Specialised Zoological (2024, 2025) classified only two species as 'HIGH' risk for their expert elicitation categorisation tailored specifically to Bonney Downs (**Table 4**).

Table 4. Bat species recorded (a) at Bonney Downs, and (b) in the Pilbara IBRA region, but not yet recorded at Bonney Downs. Bat species are arranged in order of increasing body mass. Coloured columns represent collision risk categories (Specialised Zoological 2024, Voigt et al. 2024, Reid & Baker 2025, Specialised Zoological 2025). Three species are recognised as conservation significant – listed as Vulnerable under the EPBC Act (VU) and or Priority 1 (P1) species under the Western Australian Department of Biodiversity, Conservation and Attractions (DBCA) rankings.

										Specialised Zoological			Reid & Baker 2025 ^e					Voigt et al. 2024		
Common name		Scientific name	Average body mass (g)	Wing loading	Wing aspect ratio	Roost ^a	Foraging class ^a	Number of records in the Pilbara (ALA)	Recorded mortalities elsewhere in Australia ^b	2024: Likelihood flying >50 m altitude ^c	2025: Collision risk scores	2025: Collision risk category	Flight height ^d	Flight morphology ^e	Habitat ^f	Overall score	Overall risk	Threat: Fatalities	Threat: Habitat loss	Threat: Displacement
a. Recorded at Bonney Downs																				
Vespertilionidae	Finlayson's cave bat	<i>Vespadelus finlaysoni</i>	4.3	5.19±0.4	6.17±0.12	C	E	576	0	Low	4	Med	3	1	2	3.831	Low	High	Med	High
Vespertilionidae	Little broad-nosed bat	<i>Scotorepens greyii</i>	6.4	6.2±0.4	6.23±0.07	T	O	98	1	Low	4	Med	4	1	1	4.194	Medium	High	Med	High
Rhinonycteridae	Pilbara leaf-nosed bat Pilbara (VU)	<i>Rhinonictis aurantia</i>	8.3	NA	NA	C	O	15	0	Low	1	Low	3	1	5	5.300	High	Unknown	Unknown	Unknown
Vespertilionidae	Gould's wattled bat	<i>Chalinolobus gouldii</i>	9.8	8.73±1.3	6.65±0.58	T	O	138	493	Low	4	Med	4	2	1	4.451	Medium	High	Med	High
Molossidae	Northern free-tailed bat	<i>Ozimops lumsdenae</i>	12.2	NA	NA	T	O	83	0	Med	4	Med	4	2	2	4.302	Medium	High	Med	High
Molossidae	Greater northern free-tailed bat	<i>Chaerephon jobensis</i>	20.4	13.1±1.6	8.04±0.02	T	O	65	0	Med	4	Med	5	2	1	4.735	Medium	High	Med	High
Emballonuridae	Common sheath-tailed bat	<i>Taphozous georgianus</i>	26.2	9±0.8	7.74±0.24	C	O	273	0	High	9	High	5	2	2	4.510	Medium	High	Med	High
Molossidae	White-striped free-tailed bat	<i>Austronomus australis</i>	37.6	16.7±1.2	9.715±0.06	T	O	5	1420	High#	3	Med	5	3	1	5.031	High	High	Med	High
Emballonuridae	Yellow-bellied sheath-tailed bat	<i>Saccolaimus flaviventris</i>	44	12.95±0.6	8.085±0.26	T	O	12	5	Med	6	Med	5	3	1	4.670	Medium	High	Med	High
Megadermatidae	Ghost bat (VU)	<i>Macroderma gigas</i>	103.4	16.8	6.1	C	E	104	0	Med			3	3	4	5.613	High	Low	Unknown	Unknown
b. Recorded in the Pilbara, but not at Bonney Downs as part of the regular surveys																				
Vespertilionidae	Arnhem long-eared bat	<i>Nyctophilus arnhemensis</i>	6.6					10	0		OOR		2	1	2	3.400	Low	Low	High	High
Molossidae	Northern coastal free-tailed bat (P1)	<i>Ozimops cobourgiensis</i>	7.3					33	0		OOR		4	1	5	4.445	Medium	High	Med	High
Vespertilionidae	Lesser long-eared bat	<i>Nyctophilus geoffroyi</i>	8.0					53	26		P ^g		3	1	1	3.717	Low	Low	High	High
Vespertilionidae	Pallid long-eared bat	<i>Nyctophilus daedalus</i>	8.9					30	0		P ^g		2	1	2	3.400	Low	Low	High	High
Vespertilionidae	Inland broad-nosed bat	<i>Scotorepens balstoni</i>	9.3					11	0		OOR		4	2	1	4.451	Medium	High	Med	High
Emballonuridae	Hill's sheath-tailed bat	<i>Taphozous hilli</i>	27.3					49	1		NR ^h		5	2	4	4.831	High	High	Med	High
Pteropodidae	Little red flying-fox	<i>Pteropus scapulatus</i>	384.0					9	0		NR		5	5	2	6.246	High	Unknown	High	Unknown
Pteropodidae	Black flying-fox	<i>Pteropus alecto</i>	674.0					78	0		P ⁱ		5	5	3	6.388	High	High	Low to Med	Unknown

^a Roost: C=cave, T=tree; Foraging class: O=open – forage over the canopy using straight, unobstructed flight paths more than 4 m above the general canopy of the vegetation. E=edge-foraging species foraging against and within vegetation, rarely above vegetation. Given the low density of vegetation in the Pilbara, there are no true closed canopy (clutter) foragers.

^b mortalities reported by Moloney et al. (2019) (recorded from Victorian windfarms between 2003-2018), review of 12 BABMP annual reports (open access) from within Australia (from 2019-2025) reporting mortalities (see Interim Report for Project 4.2 Mortality Monitoring), Nature Advisory (IBRC presentation 2025) and Gratton (2025).

^c Estimated risk scores for each bat species recorded in the 2023-2024 surveys at Bonney Downs, based on an authoritative estimate of which species are likely to be flying at >50 m in altitude (Specialised Zoological 2024, 2025). Reid and Baker (2025) categories: (1) Flight height^d 1= trawlers that capture prey on the surface of water bodies; 2=foliage gleaners that capture non-flying prey; 3=close clutter aerial foragers that typically forage below canopy height; 4=outer canopy foragers; 5=open space aerial foragers and commuters. (2) Flight morphology^e see Table 2 for interpretation. (3) Habitat^f see Table 3 for interpretation.

Austronomus australis is ranked HIGH risk based on mortalities elsewhere in Australia – representing ~50% of mortalities as operational wind farms (mostly in Victoria and NSW) (Bennett 2025) – but has not been commonly recorded in the Pilbara (ALA records and data collected for BBSUS carried out at Bonney Downs).

OOOR: Bonney Downs is out of range. P^g *Nyctophilus daedalus* and *Nyctophilus geoffroyi* might be present but their echolocation calls are usually low in amplitude, and can be difficult to distinguish from clutter calls of *Scotorepens greyii*; some *Nyctophilus acoustic* records have been reported in Feb 2025 and August 2025 (SZ 2025). NR not recorded. NR^h *Taphozous hilli* could be present in addition to *T. georgianus*, given its distribution in the region (Milne et al. 2023), but its calls cannot be distinguished reliably from those of *T. georgianus*. Pⁱ present, but only recorded at one palm tree on the site.

5.2 Pilbara leaf-nosed bat *Rhinonictoris aurantia* (Pilbara Form)

The Pilbara leaf-nosed bat *Rhinonictoris aurantia* (Pilbara Form) (8.3 g; Rhinonycteridae) is known as a strong, highly acrobatic and high energy flier that forages in cluttered environments around vegetation. Their extremely high frequency echolocation call provides high resolution against vegetation. Their call is a combination CF-FM call (**Figure 4**) characterised by a CF component 5-8 milliseconds in duration at a characteristic frequency at 121 kHz that provides the bat information on velocity/glint detection, and terminating in a steep downward FM sweep spanning c. 20 kHz for range/detail (Queensland Government nd).

These bats typically fly in a zig-zag pattern with high manoeuvrability (flight mobility score 1; Reid & Baker 2025), flying low to the ground (less than 3 m) often near water sources, gorges, and cave entrances (Churchill *et al.* 1988). The Pilbara leaf-nosed bat has been observed foraging in a variety of habitats—*Triodia* hummock grasslands covering low rolling hills and shallow gullies, over small watercourses and pools amongst granite boulder terrain, around rock outcrops, low shrublands in ironstone gorges, and above low shrubland (Bullen 2021). Their foraging flight height is recognised by a relatively low threat score (flight height 3; Reid & Baker 2025). While they forage over a wide range of habitats (SPRAT 2025), their call structure is suggestive of specialisation, and they have been grouped in the highest score for foraging habitat specialisation (habitat 5; Reid & Baker 2025).

These bats are highly selective about their roosts, requiring deep caves or disused mines with stable, high-temperature (28–32 °C) and high-humidity (85–100%) microclimates. The limited availability of these specific roosts is a major constraint on their distribution, and displacement from suitable roosts is recognised as a key threat (SPRAT 2025). Together with their Vulnerable population status, wind turbines are believed to represent HIGH overall risk (overall risk score 5.30; Reid & Baker 2025) for *Rhinonictoris aurantia* (Pilbara Form). However, expert elicitation for the Bonney Downs study site classifies this species as having LOW likelihood of flying above 50 m (Specialised Zoological 2024) and, coupled with low activity records, the species is overall classed as LOW risk of wind turbine collision (Specialised Zoological 2025).

Pilbara leaf-nosed bat *Rhinonictoris aurantia* (Pilbara form) (edge³ foraging) was only rarely recorded from the Bonney Downs project area (12 records; 0.01% of acoustic records) indicating that they are an infrequent visitor. All of the records occurred after 8 pm and before 3 am (20:00 1 record, 21:00 1 record, 23:00 2 records, 12:00 1 record, 1:00 2 records, 2:00 2 records, 3:00 3 records; **Figure 6**), indicating that these bats were not roosting near the proposed wind farm site. No known Pilbara leaf-nosed bat roosts have been identified near the Bonney Downs project. All Pilbara leaf-nosed bat calls were recorded on the northern and north-eastern parts of Bonney Downs (**Figure 7**) which aligns with the closest known roost site being located at the old Copper Hills mine, located ~32 km north of Bonney Downs (SPRAT 2025). Recent pit-tag tracking of Pilbara leaf-nosed bat has shown movements of ~65 km in 5 hours (O'Brien, J, 2025), making this distance easily traversable for these small (~8.3 g) bats.

³ Edge-foraging bats are insect-eating bats that hunt along the boundaries between different habitats (like forest edges, field margins, or waterways) because these 'edges' concentrate prey and offer navigation cues, acting as crucial foraging grounds and corridors for many aerial insectivores.

Bat activity by species, season, and time of night



Figure 6. Plots showing numbers of detections of 8 bat species recorded at Bonney Downs, shown by hour of the night and season of the survey. Bat species are shown top-to-bottom by roost type and then by increasing order of body mass. The first three species roost in caves (black line), while the remaining species make use of trees; green indicates edge-foraging species and blue open foraging species. Note that *Austronomus australis* and *Nyctophilus* sp. have been recorded only scarcely, while Ghost bats and Black flying-fox have not been recorded as part of the auditory surveys at Bonney Downs, but they have been detected using acoustic lures or direct observation, respectively.

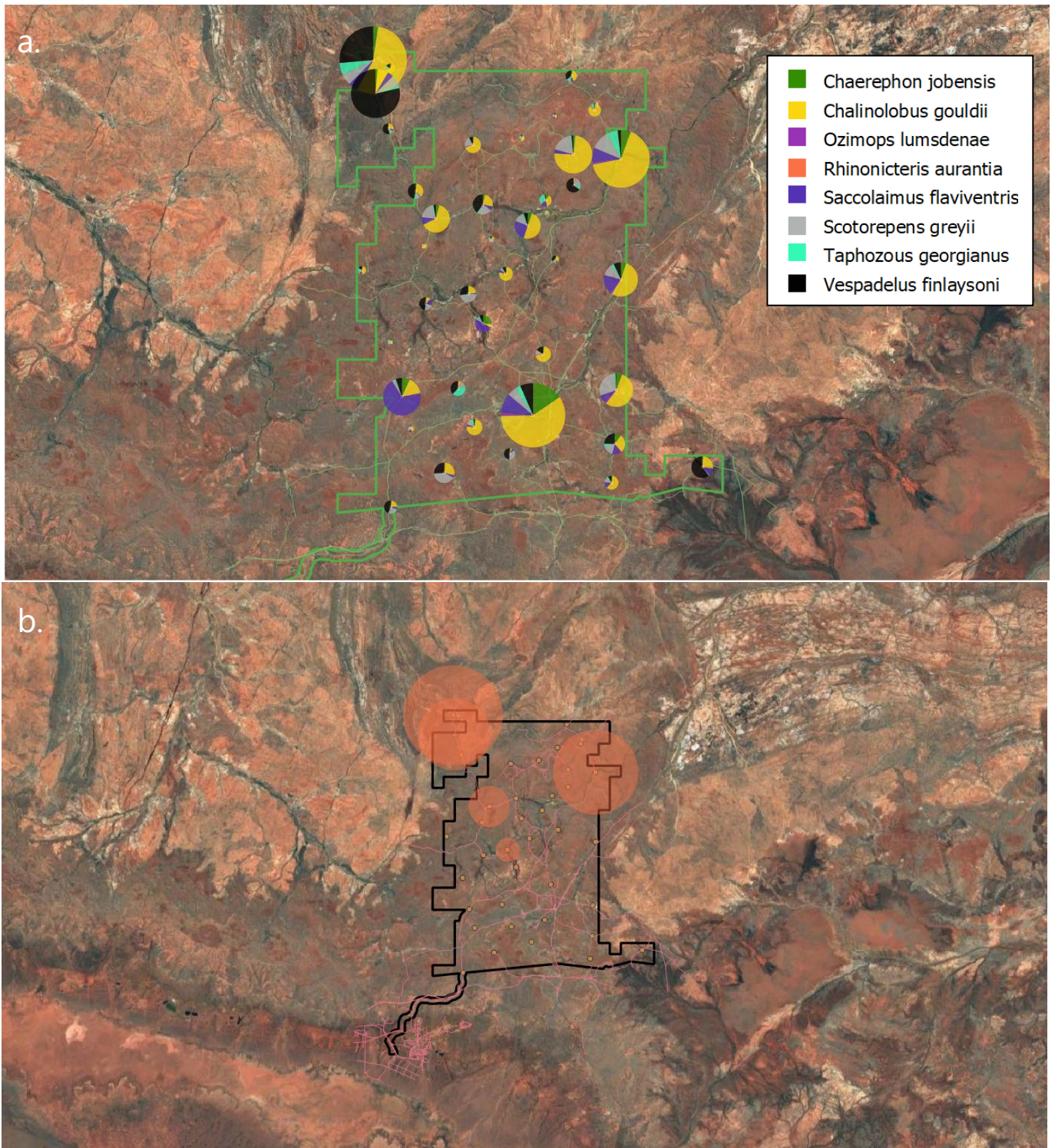


Figure 7. (a) Bat species recorded at Bonney Downs BBSUS (ultrasonic recorders positioned at ground level) and (b) Records of Pilbara leaf-nosed bats.

5.3 Ghost bat *Macroderma gigas*

Only a single Ghost bat *Macroderma gigas* record has been made for Bonney Downs to date (0.001% of all bat records). The record was from 18:52, ~30-40 minutes after sunset. The nearest artificial Ghost bat roost is ~37 km to the east, and the nearest natural roost 58 km to the south-southwest.

The Ghost bat *Macroderma gigas* (103.4 g; Megadermatidae) stands out as an outlier amongst the other Bonney Downs bat species in terms of its flight characteristics (**Figure 8**). These carnivorous bats have relatively low wing loading (for their body mass) (<36) but also low aspect ratio (≤ 6.3), traits that are characteristic for carnivorous bat species (Norberg & Fenton 1988). This wing morphology is an adaptation for high manoeuvrability (flight morphology score 3; Reid & Baker 2025) in cluttered environments for capture of agile vertebrate prey, rather than fast, long-distance flight.

The Ghost bat employs a hunting strategy that involves ambushing prey from a perch, which is a form of hunting often referred to as 'sit and inspect', and is a variation of 'hawking'. The bat hunts prey against surfaces (e.g., the ground, vegetation) in acoustically complex or 'cluttered' microhabitats, relying on good vision and prey-generated sounds rather than solely on echolocation to locate targets. This foraging strategy means that it does not fly high (flight height 3; Reid & Baker 2025), but selectively forage at sites 30-70% ground cover (Trainer *et al.* 2025) and require trees for perching (foraging habitat 4; Reid & Baker 2025). These bats may fly substantial distances to find a favoured hunting position, with average nightly distances of 16 km [range 2–63 km] recorded for 40 GPS tracked individuals at multiple sites across the Pilbara (Trainer *et al.* 2025).

Largely due to their Vulnerable population status, wind turbines are believed to represent HIGH overall risk (overall risk score 5.61; Reid & Baker 2025) for Ghost bats. However, given their low activity recorded, expert elicitation for the Bonney Downs study site classifies this species has having MEDIUM likelihood of flying above 50 m (Specialised Zoological 2024), which supports data for GPS tracking (Trainer *et al.* 2025), but a LOW overall collision risk on account of low frequency of occurrence at the Bonney Downs site.

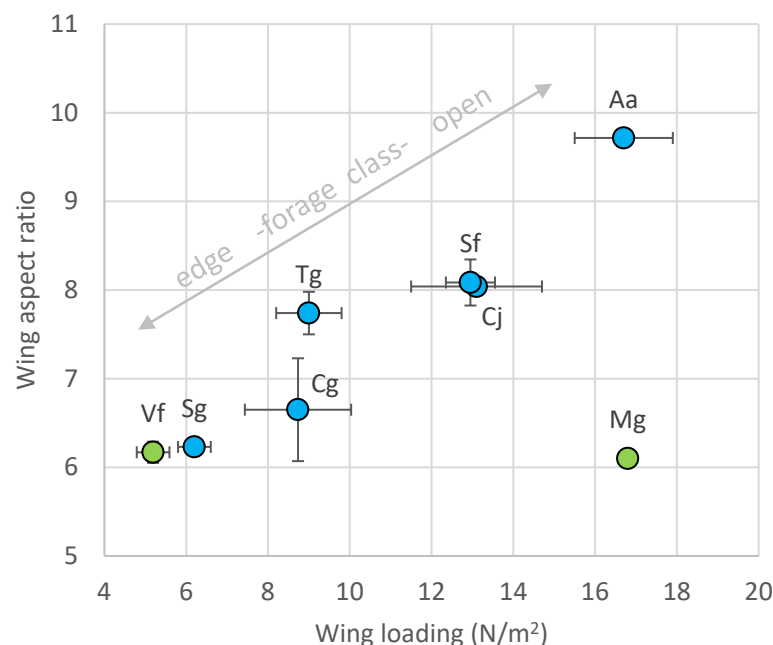


Figure 8. Comparison between available data on wing loading and wing aspect ratio for bat species recorded at Bonney Downs (Crane *et al.* 2022). The Ghost bat (Mg) stands out as an outlier in this relationship. Colours represent foraging class: green = clutter and blue = open. Species are named by initials (Genus species).

6 Discussion

A total of 10 microbat species and one flying fox species have been recorded at Bonney Downs. There are no available data of collision fatalities for 4 of the 10 microbat species, as their geographic range does not currently overlap with operational wind farms. Two bat species present are conservation significant:

Pilbara leaf-nosed bat *Rhinonictoris aurantia* (Pilbara form) is considered to be at LOW overall collision risk due to the following factors

- Reid and Baker (2025) have classified this species as overall HIGH risk rating. This classification was largely contributed to by scores for population vulnerability (conservation rating) and a value assessment of high foraging habitat selectivity. However, the same authors attributed low risk scores for flight height and flight mobility score. Ecological (foraging strategy) and biological (wing morphology) information indicates that this species forages close to the ground near vegetation and is unlikely to fly into the rotor swept area. Expert elicitation for the Bonney Downs study site similarly classifies this species has having LOW likelihood of flying above 50 m⁴ (Specialised Zoological 2024). No roost structures have been recorded on Bonney Downs, and based on call data, no roosts appear likely to occur within Bonney Downs. Occurrence within the Bonney Downs project area is considered low, with only infrequent foraging activity recorded. Coupled with low activity records the species is therefore overall classed as LOW risk of wind turbine collision (Specialised Zoological 2025).
- There are no turbine collisions records for the entire species' range of *Rhinonictoris aurantia*.

Ghost bat *Macroderma gigas* is considered to be a LOW overall collision risk due to the following factors

- Reid and Baker (2025) have classified this species as overall HIGH risk. This classification was largely contributed to by scores for population vulnerability (conservation rating) and foraging habitat selectivity (these bats require trees for their sit-and-wait hunting). The authors also gave the species a relatively high risk score for flight mobility; this scoring could reflect the large size of the bat, but wing morphology data indicates high manoeuvrability for the species (Norberg & Fenton 1988, Crane *et al.* 2022). Reid and Baker (2025) attributed LOW risk scores for flight height (i.e., collision risk), which is consistent with available data derived from GPS tracking for the species (Trainer *et al.* Biological Conference). Expert elicitation for the Bonney Downs study site classifies this species has having MEDIUM likelihood of flying above 50 m⁵ (Specialised Zoological 2024), also supporting GPS tracking results for the species (Trainer *et al.* 2025).
- No roost structures have been recorded on Bonney Downs, and based on call data, no roosts appear likely to occur within Bonney Downs. Occurrence within the Bonney Downs project area is considered low, with a single observation recorded during BBSUS.
- Ecological and biological information indicates that this species hunts prey species using an ambush strategy, with good visual perception, which would limit it flying within the rotor sweep area and should enable good perception of turbine blades.
- While the range of the Ghost bat *Macroderma gigas* does overlap with wind farms in northern Queensland, there are no available records of collision fatalities for this species.

⁴ Noting that the wind turbines proposed for Bonney Downs will have a rotor swept area of ~100–300 m, and therefore greater ground clearance than accounted for by these authors.

⁵ Noting that the wind turbines proposed for Bonney Downs will have a rotor swept area of ~100–300 m, and therefore greater ground clearance than accounted for by these authors.

7 References

- Arnett, E. B., et al. (2008) Patterns of bat fatalities at wind energy facilities in North America. *The Journal of Wildlife Management*, **72**, 61.
- Aronson, J. (2022) Current state of knowledge of wind energy impacts on bats in South Africa. *Acta Chiropterologica*, **24**, 221.
- Australian Museum, (2025) Australian bats. Inland Cave Bat, Scientific name: *Vespadelus finlaysoni*. The Australian Museum, Sydney, NSW.
- Baerwald, E. F. & R. M. R. Barclay (2009) Geographic variation in activity and fatality of migratory bats at wind energy facilities. *Journal of Mammalogy*, **90**, 1341.
- Barré, K., I. Le Viol, Y. Bas, R. Julliard & C. Kerbiriou (2018) Estimating habitat loss due to wind turbine avoidance by bats: Implications for European siting guidance. *Biological Conservation*, **226**, 205.
- BatMap, (2021) BatMap Polygons. Australian Bat Society, Inc. <https://www.ausbats.org.au/batmap.html>
- Bennett, E., 2025: *Wind energy and bats in Australia*.
- Bolívar-Cimé, B., A. Bolívar-Cimé, S. A. Cabrera-Cruz, Ó. Muñoz-Jiménez & R. Villegas-Patracá (2016) Bats in a tropical wind farm: species composition and importance of the spatial attributes of vegetation cover on bat fatalities. *Journal of Mammalogy*, **97**, 1197.
- Bullen, R. D., (2021) A review of Pilbara leaf-nosed bat ecology, threats and survey requirements. Prepared for the Department of Agriculture, Water and Environment. Canberra, ACT, Bat Call WA, Hillarys, Western Australia. <https://www.dcceew.gov.au/environment/epbc/publications/review-pilbara-leaf-nose-bat>
- Churchill, S. (2008a) *Australian bats*, 2nd edn. Sydney, NSW: Allen & Unwin.
- Churchill, S. K. (2008b) *Australian Bats*, 2nd edn. Crows Nest, NSW: Allen and Unwin.
- Churchill, S. K., P. M. Helman & L. S. Hall (1988) Distribution, populations and status of the orange horseshoe bat, *Rhinonictis aurantius* (Chiroptera: Hipposideridae). *Australian Mammalogy*, **11**, 27.
- Crane, M., I. Silva, M. J. Grainger & G. A. Gale (2022) Limitations and gaps in global bat wing morphology trait data. *Mammal Review*, **52**, 165.
- Crane, M., I. Silva, M. J. Grainger & G. A. Gale (2025) Predicting risk to bat species from wind turbine collision in Southeast Asia. *Conservation Biology*, **39**, e14452.
- Cryan, P. M. & R. M. R. Barclay (2009) Causes of bat fatalities at wind turbines: hypotheses and predictions. *Journal of Mammalogy*, **90**, 1330.
- Cryan, P. M., et al. (2014) Behavior of bats at wind turbines. *Proceedings of the National Academy of Sciences*, **111**, 15126.
- DAWE, (2021) Onshore Wind Farms - interim guidance on bird and bat management. Department of Agriculture, Water and the Environment, Australian Government, Canberra, ACT, Australia. https://mcusercontent.com/00da74a85695b090a178fdd06/files/a7b60289-7890-b14d-a457-e4e98af7829c/BBMP_guidance_10_December_2021_DAWE.pdf?mc_cid=bdca4f55de&mc_eid=d7e09e3f06
- DCCEEW, (2023) Onshore Wind Farm Guidance. Department of Climate Change, Energy, the Environment and Water, Canberra, ACT, Australia.
- DCCEEW, (2024) Onshore Wind Farm Guidance. Best practice approaches when seeking approval under Australia's national environment law. Department of Climate Change, Energy, the Environment and Water, May 2024. CC BY 4.0., Canberra, ACT.
- Ecogeneration, (2023) Wind map of Australia 2023. Rystad Energy, Sydney, NSW. https://www.ecogeneration.com.au/wp-content/uploads/2023/03/2023_WindMap.pdf
- Ellerbrok, J. S., A. Delius, F. Peter, N. Farwig & C. C. Voigt (2022) Activity of forest specialist bats decreases towards wind turbines at forest sites. *Journal of Applied Ecology*, **59**, 2497.
- Fenton, M. B. (1990) The foraging behaviour and ecology of animal-eating bats. *Canadian Journal of Zoology*, **68**, 411.
- Ferreira, D., C. Freixo, J. A. Cabral, R. Santos & M. Santos (2015) Do habitat characteristics determine mortality risk for bats at wind farms? Modelling susceptible species activity patterns and anticipating possible mortality events. *Ecological Informatics*, **28**, 7.
- Ferrer, M., M. de Lucas, G. F. E. Janss, E. Casado, A. R. Munoz, M. J. Bechard & C. P. Calabuig (2012) Weak relationship between risk assessment studies and recorded mortality in wind farms. *Journal of Applied Ecology*, **49**, 38.
- Forcey, G., M. Krogh & T. Waldo, (2012) A habitat-based wind-wildlife collision model with application to the Upper Great Plains Region. Technical report, Normandeau Associates, Inc.
- Frick, W. F., et al. (2017) Fatalities at wind turbines may threaten population viability of a migratory bat. *Biological Conservation*, **209**, 172.
- Global Wind Atlas, (2025) wind resources in Australia (AUS_wind-speed_200m). W. B. Group (Ed.).
- Gration, R., (2025) A qualitative traits-based approach to developing wind-turbine collision vulnerability profiles for Australian microbats. In: *International Bat Research Conference*. Cairns, Queensland, Australia.
- Hull, C. & L. Cawthen (2013) Bat fatalities at two wind farms in Tasmania, Australia: bat characteristics, and spatial and temporal patterns. *New Zealand Journal of Zoology*, **40**, 5.

- Jolly, S. (1990) The biology of the common sheath-tail bat, *Taphozous georgianus* (Chiroptera, Emballonuridae), in Central Queensland. *Australian Journal of Zoology*, **38**, 65.
- Korner-Nievergelt, F., R. Brinkmann, I. Niermann & O. Behr (2013) Estimating bat and bird mortality occurring at wind energy turbines from covariates and carcass searches using mixture models. *PloS One*, **8**, e67997.
- Kunz, T. H., E. B. Arnett, B. M. Cooper, W. P. Erickson, R. P. Larkin, T. Mabee, M. L. Morrison, M. D. Strickland & J. M. Szewczak (2007) Assessing impacts of wind-energy development on nocturnally active birds and bats: a guidance document. *The Journal of Wildlife Management*, **71**, 2449.
- Lentini, P., L. Lumsden & E. van Harten, (2025a) Assessment, mitigation and monitoring of turbine collision impacts on wildlife: An international systematic review. In: *International Bat Research Conference*. Cairns, Queensland, Australia.
- Lentini, P. E., L. F. Lumsden & E. M. v. Harten, (2025b) Assessment, mitigation and monitoring of onshore wind turbine collision impacts on wildlife - A systematic review of the international peer-reviewed literature, and its relevance to the Victorian context Arthur Rylah Institute for Environmental Research Technical Report Series No. 389.
https://www.ari.vic.gov.au/_data/assets/pdf_file/0023/746060/ARI-Technical-Report-389-Systematic-review-of-onshore-wind-farm-collisions.pdf
- Lintott, P. R., S. M. Richardson, D. J. Hosken, S. A. Fensome & F. Mathews (2016) Ecological impact assessments fail to reduce risk of bat casualties at wind farms. *Current Biology*, **26**, R1135.
- Maclaurin, G., C. Hein, T. Williams, O. Roberts, E. Lantz, G. Buster & A. Lopez (2022) National-scale impacts on wind energy production under curtailment scenarios to reduce bat fatalities. *Wind Energy*, **25**, 1514.
- Menkhorst, P. & F. Knight (2001) *A Field Guide to the Mammals of Australia*. Oxford, U.K.: Oxford University Press.
- Milne, D. J., T. B. Reardon & G. Ford (2023) BatMap—authoritative distribution maps for Australian bats. *Australian Mammalogy*, **45**, 350.
- Moloney, P., L. Lumsden & I. Smales, (2019) Investigation of existing post-construction mortality monitoring at Victorian wind farms to assess its utility in estimating mortality rates. Arthur Rylah Institute for Environmental Research Technical Report Series No. 302. , Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Morant, J., L. Naves-Alegre, H. M. García, E. Tena, S. Sánchez-Navarro, J. Nogueras, C. Ibáñez, E. Sebastián-González & J. M. Pérez-García (2025) Mapping bird and bat assemblage vulnerability for predicting wind energy impact. *Journal of Environmental Management*, **380**, 124961.
- Norberg, U. M. & M. B. Fenton (1988) Carnivorous bats? *Biological Journal of the Linnean Society*, **33**, 383.
- Norberg, U. M. & J. M. V. Rayner (1987) Ecological morphology and flight in bats (Mammalia; Chiroptera): wing adaptations, flight performance, foraging strategy and echolocation. *Philosophical Transactions of the Royal Society of London. B, Biological Sciences*, **316**, 335.
- NSW, (2025) Yellow-bellied Sheath-tail-bat - profile. NSW Government, Office of Environment and Heritage.
<https://threatenedspecies.bionet.nsw.gov.au/profile?id=10741>
- Parnaby, H. E., A. G. King & M. D. B. Eldridge (2021) A new bat species from southwestern Western Australia, previously assigned to Gould's Long-eared Bat *Nyctophilus gouldi* Tomes, 1858. *Records of the Australian Museum*, **73**, 53.
- Queensland Government, (nd) Orange leaf-nosed bat *Rhinonictis aurantia* Vulnerable. In: *Targeted species survey guidelines*. Ecological Sciences, Queensland Herbarium, Brisbane, Queensland.
- Reardon, T. B., N. L. McKenzie, S. J. B. Cooper, B. Appleton, S. Carthew & M. Adams (2014) A molecular and morphological investigation of species boundaries and phylogenetic relationships in Australian free-tailed bats *Mormopterus* (Chiroptera: Molossidae). *Australian Journal of Zoology*, **62**, 109.
- Reid, K. & G. B. Baker, (2025) Impacts on birds and bats from onshore wind farms in Australia. An ecological risk assessment. Ross Analytics Pty Ltd and Latitude 42 Environmental Consultants Pty Ltd. Report prepared for the Department of Climate Change, Energy, the Environment and Water. CC BY 4.0, Canberra, ACT.
- Reimer, J. P., E. F. Baerwald & R. M. R. Barclay (2010) Diet of hoary (*Lasiurus cinereus*) and silver-haired (*Lasionycteris noctivagans*) bats while migrating through southwestern Alberta in late summer and autumn. *The American Midland Naturalist*, **164**, 230.
- Reusch, C., A. A. Paul, M. Fritze, S. Kramer-Schadt & C. C. Voigt (2023) Wind energy production in forests conflicts with tree-roosting bats. *Current Biology*, **33**, 737.
- Rydell, J., L. Bach, M.-J. Dubourg-Savage, M. Green, L. Rodrigues & A. Hedenström (2010) Mortality of bats at wind turbines links to nocturnal insect migration? *European Journal of Wildlife Research*, **56**, 823.
- Scarff, F. & J. Shephard, (2025) Bird and Bat Management Plan science for wind energy developments. Project 2.2.1 Species Distribution Modelling. Draft Report: Appendix B Sensitive Species. Interim Report prepared for Fortescue Ltd. Harry Butler Institute, Perth, Western Australia.
- Schnitzler, H.-U. & E. K. V. Kalko (2001) Echolocation by insect-eating bats: we define four distinct functional groups of bats and find differences in signal structure that correlate with the typical echolocation tasks faced by each group. *Bioscience*, **51**, 557.

- Schunk, C., S. M. Swartz & K. S. Breuer (2017) The influence of aspect ratio and stroke pattern on force generation of a bat-inspired membrane wing. *Interface Focus*, **7**, 20160083.
- Shaw, R. E., et al. (2025) Modelling complex habitat use for threatened bat species decision-making in landscapes with competing priorities. <https://doi.org/10.32942/X29640>.
- Smallwood, K. S. & D. A. Bell (2020) Relating bat passage rates to wind turbine fatalities. *Diversity*, **12**, 84.
- Specialised Zoological, (2024) Identification of bat species from Bonney Downs, Western Australia. Prepared for Ecologia Environment Pty Ltd. Version 22 August 2024. SZ project reference SZ720.
- Specialised Zoological, (2025) Identification of bat species from Bonney Downs, Western Australia. October 2023 – August 2025. Prepared for Ecologia Environment Pty Ltd. Version 1 December 2025. SZ project reference SZ761.
- SPRAT, (2025) *Rhinonictis aurantia*. Species Profile and Threats Database. Department of Climate Change, Energy, the Environment and Water, Canberra, ACT. <https://www.environment.gov.au/sprat>
- Thaxter, C. B., et al. (2017) Bird and bat species' global vulnerability to collision mortality at wind farms revealed through a trait-based assessment. *Proc. Roy. Soc. B*, **284**, 20170829.
- Trainer, J., S. Reiffer & R. Bullen, (2025) GPS tracking of the Pilbara Ghost bat. In: *Biodiversity Conference*: 124. Perth, Western Australia.
- Voigt, C. C., et al. (2024) Toward solving the global green–green dilemma between wind energy production and bat conservation. *BioScience*, **74**, 240.
- Voigt, C. C., L. S. Lehnert, G. Petersons, F. Adorf & L. Bach (2015) Wildlife and renewable energy: German politics cross migratory bats. *European Journal of Wildlife Research*, **61**, 213.
- Woinarski, J. C. Z., A. A. Burbidge & P. L. Harrison (2014) *The Action Plan for Australian Mammals 2012*. Collingwood, Victoria: CSIRO Publishing.

8 Appendices

8.1 Literature review for the impact of wind turbines on wildlife

Identification

A systematic search was conducted using structured keywords related to bats, wind-energy infrastructure, and collision risk modelling. The full Boolean search structure was:

- bat AND ("wind turbine" OR "wind farm" OR "windfarm" OR windmill)
- AND ("collision model" OR "CRM" OR "collision risk model")

Searches were run using OpenAlex and Publish or Perish (Google Scholar).

Search term subsets produced the following example hit counts:

- bat AND "wind turbine" AND "collision risk model" → 42
- bat AND "wind farm" AND "CRM" → 16
- bat AND "windmill" AND "collision risk model" → 3

Returning 179 OpenAlex results. Google Scholar returned 104 additional results.

Screening

Across both databases, 283 records were identified. After removing 96 duplicates, 187 unique records remained. These 187 records underwent title/abstract screening. A total of 124 records were removed for being:

- generic wind-energy papers
- not related to collision risk
- non-English
- otherwise irrelevant

This left 63 records for full-text assessment.

Eligibility

Full-text screening removed 33 bird-only collision-risk studies, leaving bat-only or bat-relevant studies.

A total of 16 studies were included in the final synthesis: 14 from OpenAlex, 2 from Google Scholar (Publish or Perish)

PRISMA Summary Table

		PoP/Google Scholar	OpenAlex
Total records identified	283	104	179
Duplicates removed	96	0	96
Records screened	187		
Irrelevant / wind-energy generic / non-English removed	124	87	37
Full-text assessment for relevance:	63		
Bird-only	33	12	21
Total excluded	157		
Final included (bat-specific)	16	2	14

8.2 Appendix B. Specialised Zoological report 2024



Identification of bat species from Bonney Downs, Western Australia

Prepared for **Ecologia Environment Pty Ltd**

Version **22 August 2024**

SZ project reference **SZ720**

Specialised Zoological ABN 92 265 437 422

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This report should be included as an appendix in any larger submission to Government, and cited as:

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Version history

Date	Version	Note
2024-06-20	2024-06-20	Interim results from partial analysis of the datasets
2024-08-19	2024-08-19	Final report with outcomes from full analysis
2024-08-22	2024-08-22	Final report with addition of 2023 data

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Contents

1.0 Summary	4
1.1 Scope and data	4
1.2 Species richness	4
1.3 Ghost Bat	5
1.4 Pilbara Diamond-faced Bat	5
1.5 Bat species not detectable with the methods used	5
2.0 Methods	6
2.1 Ultrasonic recordings	6
2.2 Acoustic lure sites with infrared video recordings	6
3.0 Limitations	9
4.0 References	10
Appendix 1. Summarising collision risk—a possible starting point	28
Appendix 2. Use of acoustic lures	31

1.0 Summary

1.1 Scope and data

Bat identifications from acoustic recordings are provided from the Bonney Downs project area, in the Pilbara region of Western Australia. The datasets reported on here comprise a total of 144 sites, 320 recording nights and 475,151 WAV files:

- May 2023 'BBD' and 'BDDP' series—18 sites, 53 recording nights (119,133 sound files)
- July 2023 'BDTBD' series—4 sites, 18 recording nights (9,912 sound files)
- October 2023 'BB' and 'BDDP' series—42 sites, 80 recording nights (121,987 sound files)
- February 2024 'BB' series—39 sites, 78 recording nights (104,101 WAV sound files)
- March 2024 'BB' series—31 sites, 63 recording nights (65,952 WAV sound files)
- March 2024 'BDDP'—10 sites, 28 recording nights (54,066 WAV sound files)

Particular attention was given to the detection of two bat species of conservation significance: Ghost Bat *Macroderma gigas* (Megadermatidae) and Pilbara Diamond-faced Bat *Rhinonycteris aurantia* (Rhinonycteridae).

Two methods were used on the field survey:

1. Ultrasonic recordings with bat detectors to provide species identifications from echolocation calls;
2. Acoustic lure (portable speaker broadcasting Ghost Bat social calls; **Figure 1**) with detections and identification of the Ghost Bat from both infrared video and ultrasonic recordings; this is a targeted survey method to detect the species away from roost sites.

1.2 Species richness

Ten species of bat were detected (**Table 1; Figure 2**); which includes both the Ghost Bat and Pilbara Diamond-faced Bat. Each bat species was assigned to one of three categories representing the likelihood that they would be encountered above an altitude of 50 metres. This is an authoritative estimate based on my own accumulated casual field observations.

To give a further indication of the relative risk of collision of each species, the frequency of detection was calculated across sites for each species on each survey, and across all sites (**Table 2**). A risk matrix was devised based on the likelihood of detection at height categories and the frequency of detection values, which might be useful as a 'starting point' (conjecture) for considering the relative risk of collision with a turbine for each species (**Appendix 1**).

Details of detections at each site (collated across recording nights per site) are summarised in **Tables 3 – 8**.

One interesting observation was made for a high-flying species: the White-striped Free-tailed Bat *Austronomus australis* (Molossidae) is only seasonally present in the region from April to September according to an analysis presented by Bullen and McKenzie (2005). Observations

from the surveys were consistent with this analysis, with *A. australis* being detected only on the May and July 2023 surveys.

1.3 Ghost Bat

The Ghost Bat was detected at one acoustic lure site: BDGB03. One ‘fly-by’ was observed in video recordings on both infrared camera traps at 18:52:22 and 18:52:54 (**Table 9**). The identification was based on the observation of an anteriorly-directed structure resembling long ears, the broad wings, and lack of a distinct tail (**Figure 3**; see comparison with images of birds and insects in **Figure 4**). It was not detected in echolocation recordings at the acoustic lure sites. However, the bat detector recording failed at site BDGB03. No other detections of the Ghost Bat were made on the surveys.

1.4 Pilbara Diamond-faced Bat

The Pilbara Diamond-faced Bat was detected from one echolocation sequence from acoustic lure site BDGB01 (unit 641036) on the night of 2024-03-22 at 23:21:09 (**Figure 5**). I have observed this species approaching a Ghost Bat social call broadcast on previous occasions. The Pilbara Diamond-faced Bat was also detected well after sunset and well before sunrise at 14 other sites in 2023 and 2024 (**Table 10**):

- 7 sites in May 2023
- 4 sites October 2023
- 3 sites in February 2024

1.5 Bat species not detectable with the methods used

Given that this survey was conducted to understand the possible effects of the construction and operation of wind turbines on bats, it is worth noting six species that were not detected in the analysis. Three of these are known to forage or commute above the tree canopy height and might range within the blade swept area of a wind turbine in this study area. These species cannot be detected using the methods described in the present report. Three other species not detected are either not found in this part of the Pilbara, or else have low detectability with bat detectors.

- **Black Flying-fox *Pteropus alecto* and Little Red Flying-fox *Pteropus scapulatus*** (Pteropodidae)—do not echolocate and are therefore not detected by acoustic recorders (bat detectors).
- **Hill’s Sheath-tailed Bat *Taphozous hilli*** (Emballonuridae)—could be present in addition to *T. georgianus*, given its distribution in the region (Milne et al. 2023), but its calls cannot be distinguished reliably from those of *T. georgianus*.
- **Pallid Long-eared Bat *Nyctophilus daedalus* and Lesser Long-eared Bat *Nyctophilus geoffroyi*** (Vespertilionidae)—might be present but their echolocation calls are usually low in amplitude, and can be difficult to distinguish from clutter calls of the Little Broad-nosed Bat *Scotorepens greyii*.
- **Northern Coastal Free-tailed Bat *Ozimops cobourgianus*** (Molossidae)—found only along the Pilbara coast, usually in mangal habitat.

2.0 Methods

2.1 Ultrasonic recordings

The ultrasonic recordings provided were recorded in WAV format with Titley Scientific Anabat Chorus bat detectors (sampling rate 500 kHz, set to turn on automatically at sunset and off at sunrise), and Wildlife Acoustics SM4BAT-FS bat detectors (sampling rate 384 kHz).

A multi-step acoustic analysis procedure developed to process large full spectrum echolocation recording datasets from insectivorous bats (Armstrong et al. 2021a,b) was applied to the recordings made on the survey. Firstly, the WAV files were scanned for bat echolocation calls using several parameter sets in the software SCAN'R version 1.8.3 (Binary Acoustic Technology), which also provides measurements (SCAN'R parameters) from each putative bat pulse. The outputs were then used to determine if putative bat pulses measured in SCAN'R could be identified to species. This was done using a custom [R] language application that performed three tasks:

1. undertook a Discriminant Function Analysis on training data from representative calls from the Pilbara;
2. from the measurements of each putative bat pulse from SCAN'R, calculated values for the first two Discriminant Functions that could separate the echolocation call types derived from the analysis of training data, and plotted these resulting coordinates over data ellipses representing one standard deviation of the variation for the defined call types; and
3. facilitated an inspection in a spectrogram of multiple examples of each call type for each recording night by opening the original WAV files containing pulses of interest in ADOBE AUDITION version 23.1.

Species were identified based on information in the author's unpublished material and Churchill (2008). Nomenclature follows Jackson and Groves (2015). Identifications were supported by distribution information in a curated source of distribution records maintained by the Australasian Bat Society, Inc. (<https://www.ausbats.org.au/batmap.html>) (Milne et al. 2023). Custom [R] language scripts were used to summarise the analysis outcomes.

2.2 Acoustic lure sites with infrared video recordings

An acoustic lure system was set at seven sites for one night each. This method is based on recent demonstrations of its utility by Hanrahan et al. (2023) and Ruykys et al. (2023), and is broadly consistent with guidelines on the approach released in the Northern Territory (Ruykys et al. 2024). The system comprised a portable speaker (generic brand from Amazon), an Anabat Chorus bat detector, two infrared-capable camera traps (Jaycar model QC8051), and two 'long range infrared spotlights' (Jaycar model QC3654).

The portable speakers were loaded with a micro-SD card containing a sequence of sound files comprising 'squabble' calls; *sensu* Hanrahan et al. 2023; see **Appendix 2** of the Ghost Bat. Sound files consisted of a 2-minute period with various examples of squabble calls, followed by a 2-minute period of silence. The speakers played sound files on a memory card

sequentially upon startup, for the entire night. The speaker volume was maximised. The distance at which Ghost Bats can hear the signals at night is unknown but assumed to be at least 100 m.

The camera trap was set to record back-to-back 3-minute black and white video files at high resolution (4K 3840 x 2160) continuously upon start up. Recordings were started after covering the camera lens so that the unit switched from colour to night (black and white) mode. The settings were adjusted so that built-in infrared LEDs were non-functional, and infrared light was instead provided by the long-range infrared spotlight, which was powered by 10 AA batteries that lasted c. 5 hours. Each camera trap contained a blank 256 GB Sandisk SD card, which had the capacity to save the recording from a full night.

The Chorus bat detector was placed on the central star picket underneath the portable speaker to maximise the chance of detection via echolocation calls if a Ghost Bat approached the speaker. Detection of echolocation calls provides a way to independently validate any detection made from the video recordings (**Appendix 2**).



Figure 1. Representation of the acoustic lure system deployment. There are two camera traps for redundancy and corroboration of images of bats, and a bat detector for validation of an identification made from videos based on echolocation calls only.

All videos were processed with an expeditious and robust analysis method. A custom Python (<https://www.python.org/>) script (Dr R. C. Morgans, Supersensory Technologies Pty Ltd unpublished) applied a background subtraction algorithm from the *opencv* framework (<https://opencv.org/>) to the recordings and constructed a concatenated short video containing only portions of the recording with moving objects above a certain size. These concatenated videos are watched at <50% speed in the MPV MEDIA PLAYER (<https://mpv.io/>), which allows fine control of frame advancement. Objects of interest were located and re-examined in the original 4K recording using the embedded timestamp information.

Smaller species of bat can be seen often in the infrared videos. Without careful consideration, these species can sometimes be confused for the Ghost Bat when they fly near the speaker—a behaviour that might intuitively be expected only from the Ghost Bat. Ghost Bats can be distinguished in infrared and thermal video recordings from other bat species and insects based on the observation of any combination of the following morphological and behavioural features that provide an empirical basis for the identification:

- flight pattern (four distinct behaviours classified as: ‘circling’ of the post containing the speaker; ‘hover’ in front of the speaker; ‘long glide’ towards the speaker; and ‘drop in’ whereby they would sometimes approach at c. 2 m above the speaker and then drop vertically towards it);
- body size relative to other objects in the frame;
- large ear size;
- lack of a tail;
- bright eyeshine of the reflected infrared light from their large eyes (infrared recordings only, though not always visible); and
- corroboration with concurrently-recorded diagnostic echolocation calls (**Appendix 2**).

All bats observed in videos are examined by single manual frame advancement to check for diagnostic features. The relatively high resolution and video frame rate provides a reasonable level of image quality.

3.0 Limitations

The identifications presented in this report have been made within the following context:

1. The identifications made herein were based on the ultrasonic sound recordings made and provided by a 'third party' (the client named on the front of this report).
2. In the case of the present report, the recording equipment was set up and supplied by Specialised Zoological. The equipment was operated by the third party during the survey.
3. Other than the general location of the study area, Specialised Zoological has not been provided with detailed information of the survey area, has not made a visit to observe the habitats available for bats, nor have we visited the specific project areas on a previous occasion.
4. Specialised Zoological has had no input into the overall design and timing of this bat survey, recording site placement, nor the degree of recording site replication.
5. This version of the document supersedes any previous version, including the interim report (Specialised Zoological 2024). Previous drafts are not authorised by us for submission to the regulator or the public domain.
6. Please see **Appendix 2** for more information about the application of the acoustic lure.

4.0 References

- Armstrong K.N., Broken-Brow J., Hoyer G., Ford G., Thomas M. and Corben C. (2021a). Effective detection and identification of sheath-tailed bats of Australian forests and woodlands. *Australian Journal of Zoology* 68:346–363. <https://doi.org/10.1071/ZO20044>
- Armstrong K.N., Clarke S., Linke A., Scanlon A., Roetman P., Hitch, A.T. and Donnellan S.C. (2021b). Citizen science implements the first intensive acoustics-based survey of insectivorous bat species across the Murray-Darling Basin of South Australia. *Australian Journal of Zoology* 68: 364–381. <https://doi.org/10.1071/ZO20051>
- Bullen, R.D. and McKenzie, N.L. (2005). Seasonal range variation of *Tadarida australis* (Chiroptera: Molossidae) in Western Australia: the impact of enthalpy. *Australian Journal of Zoology* 53: 145–156.
- Churchill, S.K. (2008). *Australian bats*. 2nd ed. Allen and Unwin, Crows Nest, NSW.
- Hanrahan, N., Turbill C., Armstrong K.N., Dalziel A.H. and Welbergen J.A. (2023). Calling up ghosts: acoustic playback of social vocalisations reveals complex communication in a cryptic bat and provides a promising tool for monitoring disturbance-sensitive species. *Mammal Research*. <https://doi.org/10.1007/s13364-023-00727-w>
- Jackson, S.M. and Groves, C.P. (2015). *Taxonomy of Australian mammals*. CSIRO Publishing, Victoria.
- Milne D.J., Reardon T.B. and Ford G. (2023) BatMap – authoritative distribution maps for Australian bats. *Australian Mammalogy*. 45: 350–355. <https://doi.org/10.1071/AM23005>
- Ruykys, L., Hanrahan, N. and Stokeld, D. (2023). Novel acoustic lure methodology facilitates detection of the cryptic ghost bat at a landscape scale. *Wildlife Research* 51. <https://doi.org/10.1071/WR22189>
- Ruykys L., Hanrahan N. and Stokeld D. (2024) Northern Territory guidelines for surveying for the ghost bat at the landscape scale. Technical Report 05/2024, Department of Environment, Parks and Water Security, Palmerston, Northern Territory and Charles Darwin University, Brinkin, Northern Territory.
- Specialised Zoological (2024). Acoustic analysis and bat call identification from Bonney Downs, Western Australia: interim results. Unpublished report by Specialised Zoological for Ecologia Environment Pty Ltd, 20 June 2024, project reference SZ720.

Table 1. Species identified in the present survey from all sites combined. The predicted presence above 50 metres in altitude is an authoritative estimate based on my own accumulated casual field observations ('predicted to be encountered commonly above 50 m').

Predicted presence above 50 m altitude		
MEGADERMATIDAE		
Medium	Ghost Bat	<i>Macroderma gigas</i>
RHINONYCTERIDAE		
Low	Pilbara Diamond-faced Bat (Pilbara Leaf-nosed Bat)	<i>Rhinonictoris aurantia</i>
EMBALLONURIDAE		
Medium	Yellow-bellied Sheath-tailed Bat	<i>Saccolaimus flaviventris</i>
High	Common Sheath-tailed Bat	<i>Taphozous georgianus</i>
VESPERTILIONIDAE		
Low	Gould's Wattled Bat	<i>Chalinolobus gouldii</i>
Low	Little Broad-nosed Bat	<i>Scotorepens greyii</i>
Low	Finlayson's Cave Bat	<i>Vespadelus finlaysoni</i>
MOLOSSIDAE		
High	White-striped Free-tailed Bat	<i>Austronomus australis</i>
Medium	Greater Northern Free-tailed Bat	<i>Chaerephon jobensis</i>
Medium	Northern Free-tailed Bat	<i>Ozimops lumsdenae</i>

Table 2. Frequency of detection across sites for each species on each survey (higher intensity of colour for higher values).

Species	May 2024	July 2024	October 2024	February 2024 (BB series)	March 2024 (BB series)	March 2024 (BDDP series)	Over all surveys
<i>A. australis</i>	0.00	0.00	0.00	0.44	0.50	0.00	0.07
<i>C. gouldii</i>	0.87	0.77	0.80	0.94	1.00	0.74	0.85
<i>C. jobensis</i>	0.54	0.39	0.50	0.83	1.00	0.45	0.55
<i>O. lumsdenae</i>	0.18	0.26	0.00	0.11	0.50	0.14	0.18
<i>R. aurantia</i>	0.08	0.00	0.00	0.39	0.00	0.10	0.10
<i>S. flaviventris</i>	0.87	0.84	0.90	0.50	0.25	0.48	0.71
<i>S. greyii</i>	0.87	0.74	0.80	0.89	1.00	0.79	0.85
<i>T. georgianus</i>	0.77	0.61	0.80	0.83	1.00	0.50	0.70
<i>V. finlaysoni</i>	0.49	0.42	0.60	0.50	1.00	0.55	0.53

Table 3. Species detected at each site in May 2023 ('BBD' and 'BDDP' sites).

						<i>A. australis</i>	<i>C. gouldii</i>	<i>C. jobensis</i>	<i>O. lumsdenae</i>	<i>R. aurantia</i>	<i>S. flaviventris</i>	<i>S. greyii</i>	<i>T. georgianus</i>	<i>V. finlaysoni</i>
Site	Detector serial	Coordinates	First night	Last night	Nights									
BBD01	S4U06484-MDSM4-02	-22.579550, 117.011240	2023-05-27	2023-05-30	4	X	X	X	.	X	.	X	X	X
BBD02	S4U11723-MDSM4-03	-22.579550, 117.011240	2023-05-28	2023-05-29	2	X	X	X	.	X	.	X	X	X
BBD03	S4U11658-MDSM4-05	-22.579330, 117.011580	2023-05-30	2023-05-31	2	.	X	X	.	.	.	X	.	.
BBD04	S4U11723-MDSM4-03	-22.579550, 117.011240	2023-05-30	2023-05-31	2	.	X	X	.	.	X	.	.	.
BBD05	S4U06478-MDSM4-01	-22.579550, 117.011240	2023-05-30	2023-05-31	2	.	X	X	.	.	X	X	X	.
BBD06	S4U11657-MDSM4-07	-22.140550, 118.563240	2023-05-30	2023-05-31	2	X	X	X	.	X	X	X	X	X
BBD07	S4U11659-MDSM4-04	-22.579330, 117.011240	2023-05-30	2023-05-31	2	.	X	X	.	.	X	X	X	X
BBDDP02	S4U11723-MDSM4-03	-22.579550, 117.011240	2023-05-25	2023-05-27	3	.	X	X	.	.	X	X	X	X
BDBAT01	S4U11651-MDSM4-06	-22.579330, 117.011580	2023-05-28	2023-05-30	3	X	X	X	X	X	.	.	X	X
BDDP01	S4U11651-MDSM4-06	-22.579330, 117.011580	2023-05-24	2023-05-26	3	X	X	.	.	.	X	X	X	.
BDDP03	S4U06478-MDSM4-01	-22.579550, 117.011240	2023-05-23	2023-05-26	4	X	X	X	.	X	.	X	X	.
BDDP04	S4U11657-MDSM4-07	-22.140550, 118.563240	2023-05-24	2023-05-26	3	X	X	X	.	.	X	X	X	X
BDDP05	S4U11658-MDSM4-05	-22.579330, 117.011580	2023-05-23	2023-05-25	3	.	X	X	X	.	X	X	X	X
BDDP06	S4U11658-MDSM4-05	-22.579330, 117.011580	2023-05-26	2023-05-29	4	.	X	X	.	X	.	X	X	X
BDDP07	S4U11659-MDSM4-04	-22.579330, 117.011240	2023-05-26	2023-05-29	4	.	X	X	.	X	.	X	X	.
BDDP08	S4U06484-MDSM4-02	-22.579550, 117.011240	2023-05-23	2023-05-26	4	.	X	.	.	.	.	X	X	.
BDDP09	S4U06478-MDSM4-01	-22.579550, 117.011240	2023-05-27	2023-05-29	3	.	X	.	.	.	.	X	.	.
BDDP10	S4U11657-MDSM4-07	-22.140550, 118.563240	2023-05-27	2023-05-29	3	X	.	X	.	.	X	X	X	.

Table 4. Species detected at each site in July 2023 ('BDTBD' sites).

						<i>A. australis</i>	<i>C. gouldii</i>	<i>C. jobensis</i>	<i>O. lumsdenae</i>	<i>R. aurantia</i>	<i>S. flaviventris</i>	<i>S. greyii</i>	<i>T. georgianus</i>	<i>V. finlaysoni</i>
Site	Detector serial	Coordinates	First night	Last night	Nights									
BDTBD01	636494	-22.018644, 119.971222	2023-07-25	2023-07-28	4	.	X	X	X	.	.	X	X	X
BDTBD02	644439	-22.021631, 119.964485	2023-07-25	2023-07-28	4	.	X	X	X	.	.	X	X	X
BDTBD03	644439	-21.973442, 119.999969	2023-07-26	2023-07-31	6	X	X	X	.	.	.	X	X	X
BDTBD04	636494	-21.978964, 119.990219	2023-07-29	2023-08-01	4	X	X	X	.	.	X	X	X	X

Table 5. Species detected at each site in October 2023 ('BB' and 'BDDP' sites; continued next page).

						<i>A. australis</i>	<i>C. gouldii</i>	<i>C. jobensis</i>	<i>O. lumsdenae</i>	<i>R. aurantia</i>	<i>S. flaviventris</i>	<i>S. greyii</i>	<i>T. georgianus</i>	<i>V. finlaysoni</i>
Site	Detector serial	Coordinates	First night	Last night	Nights									
BDDP13	S4U06484-MDSM4-02	.	2023-10-12	2023-10-14	3	.	.	.	.	X	.	X	X	X
BB017	S4U06484-MDSM4-02	.	2023-10-15	2023-10-16	2	.	X	X	.	.	X	X	.	X
BB012	S4U06484-MDSM4-02	.	2023-10-17	2023-10-18	2	.	X	.	.	.	X	X	.	X
BB040	S4U11723-MDSM4-03	.	2023-10-09	2023-10-10	2	.	X	.	.	.	.	X	.	.
BDDP11	S4U11723-MDSM4-03	.	2023-10-11	2023-10-13	3	.	X	X	.	.	X	X	X	X
BB039	S4U11723-MDSM4-03	.	2023-10-14	2023-10-15	2	.	X	X	.	.	X	X	X	.
BB011	S4U11723-MDSM4-03	.	2023-10-16	2023-10-18	3	.	X	X	.	X	X	X	X	X
BB028	S4U11659-MDSM4-04	.	2023-10-11	2023-10-12	2	.	.	.	.	.	.	X	X	.
BB026	S4U11659-MDSM4-04	.	2023-10-13	2023-10-14	2	.	X	X	.	.	.	.	X	X
BB018	S4U11659-MDSM4-04	.	2023-10-15	2023-10-16	2	.	X	.	.	.	.	X	.	X
BB015	S4U11659-MDSM4-04	.	2023-10-17	2023-10-18	2	.	X	X	X	.	X	X	X	X
BB033	S4U11658-MDSM4-05	.	2023-10-11	2023-10-12	2	.	X	X	X	.	.	X	.	.
BB030	S4U11658-MDSM4-05	.	2023-10-13	2023-10-14	2	.	X	X	.	.	.	X	X	.
BB002	S4U11658-MDSM4-05	.	2023-10-15	2023-10-16	2	.	.	.	.	.	.	.	.	.
BB029	MDSM4-06	no data	2023-10-11	2023-10-12	2	.	.	.	.	.	.	.	.	.
BB023	MDSM4-06	no data	2023-10-13	2023-10-14	2	.	.	.	.	.	.	.	.	.
BB001	MDSM4-06	no data	2023-10-15	2023-10-16	2	.	.	.	.	.	.	.	.	.
BB007	MDSM4-06	no data	2023-10-17	2023-10-18	2	.	.	.	.	.	.	.	.	.
BB032	S4U11659-MDSM4-07	-22.045100, 119.944370	2023-10-09	2023-10-10	2	.	X	X	.	.	.	X	X	.
BB025	S4U11659-MDSM4-07	-22.045100, 119.944370	2023-10-11	2023-10-12	2	.	X	X	.	.	X	X	X	X
BB036	S4U11659-MDSM4-07	-22.045100, 119.944370	2023-10-13	2023-10-14	2	.	X	X	X	X	X	X	X	X
BB005	S4U11659-MDSM4-07	-22.045100, 119.944370	2023-10-15	2023-10-16	2	.	X	X	.	.	.	X	X	X
BB010	S4U11659-MDSM4-07	-22.045100, 119.944370	2023-10-17	2023-10-18	2	.	X	.	.	.	X	X	.	X
BB020	TC36-644436	-22.107889, 119.867348	2023-10-11	2023-10-13	2	.	X	.	.	.	X	X	.	X

						<i>A. australis</i>	<i>C. gouldii</i>	<i>C. jobensis</i>	<i>O. lumsdenae</i>	<i>R. aurantia</i>	<i>S. flaviventris</i>	<i>S. greyii</i>	<i>T. georgianus</i>	<i>V. finlaysoni</i>
Site	Detector serial	Coordinates	First night	Last night	Nights									
BB016	TC36-644436	-22.198734, 119.918373	2023-10-13	2023-10-15	2	.	X	X	X	.	X	X	.	X
BB004	TC36-644436	-21.951029, 119.794090	2023-10-15	2023-10-17	2	.	X	.	.	.	X	X	.	X
BB021	TC36-644436	-22.196741, 120.013084	2023-10-17	2023-10-19	2	.	X	.	.	.	X	X	.	.
BB037	TC39-644439	-22.045776, 119.883430	2023-10-11	2023-10-13	2	.	.	.	.	.	.	X	X	.
BB022	TC39-644439	-22.114225, 119.975815	2023-10-13	2023-10-15	2	.	X	X	.	.	X	X	X	X
BB003	TC39-644439	-21.919384, 119.782402	2023-10-15	2023-10-17	2	.	X	X	.	X	X	X	X	X
BB008	TC39-644439	no data	.	.	.	.	.	.	.	.	.	.	.	.
BB035	TC40-644440	-22.076000, 119.895966	2023-10-11	2023-10-13	2	.	X	.	.	.	X	X	X	.
BB024	TC40-644440	-21.999393, 119.954002	2023-10-13	2023-10-15	2	.	X	X	X	.	.	.	X	X
BB038	TC40-644440	-22.225801, 119.852524	2023-10-15	2023-10-17	2	.	X	X	.	.	X	X	X	X
BB013	TC40-644440	-22.256664, 119.987633	2023-10-17	2023-10-19	2	.	X	.	.	.	X	X	.	X
BB031	TC88-636488	-22.015324, 119.875801	2023-10-11	2023-10-13	2	.	X	X	X	.	X	X	X	X
BB027	TC88-636488	-21.933846, 119.972397	2023-10-13	2023-10-15	2	.	X	.	.	.	.	.	X	.
BB014	TC88-636488	-22.209757, 119.814163	2023-10-15	2023-10-17	2	.	.	.	.	.	.	X	.	.
BB019	TC88-636488	-22.174740, 119.855011	2023-10-17	2023-10-19	2	.	X	X	.	.	.	X	.	.
BDDP12	TC94-636494	-22.070423, 119.854462	2023-10-11	2023-10-14	3	.	.	.	.	.	X	X	.	X
BB034	TC94-636494	-22.092993, 119.863396	2023-10-14	2023-10-16	2	.	X	.	.	.	.	X	X	X
BB009	TC94-636494	.	2023-10-17	2023-10-17	1	.	X	.	.	.	.	X	.	.

Table 6. Species detected at each site in February 2024 ('BB' sites; continued next page).

						<i>C. gouldii</i>	<i>C. jobensis</i>	<i>O. lumsdenae</i>	<i>R. aurantia</i>	<i>S. flaviventris</i>	<i>S. greyii</i>	<i>T. georgianus</i>	<i>V. finlaysoni</i>
Site	Detector serial	Coordinates	First night	Last night	Nights								
BB001	S4U11723	-32.911090,116.475810	2024-02-09	2024-02-10	2	X	X	.	.	X	X	X	X
BB002	S4U11657	-32.816600,116.379770	2024-02-09	2024-02-10	2	X	X	.	.	X	X	.	.
BB003	S4U11659	-32.781330,116.495450	2024-02-09	2024-02-10	2	X	X	X	X	X	X	X	X
BB004	644439	-21.949577,119.793472	2024-02-09	2024-02-10	2	X	X	.	.	X	.	X	X
BB005	636494	-22.003422,119.817451	2024-02-09	2024-02-10	2	X	.	.	.	X	X	X	X
BB006	644436	-22.025839,119.844109	2024-02-09	2024-02-10	2	X	.	.	.	X	X	.	.
BB007	636494	-22.053459,119.824661	2024-02-11	2024-02-12	2	X	X	.	.	.	X	.	.
BB008	S4U11657	-32.816600,116.379770	2024-02-11	2024-02-12	2	X	X	.	.	X	X	X	X
BB009	S4U11723	-32.911090,116.475810	2024-02-11	2024-02-12	2	.	X	.	.	X	X	X	.
BB010	S4U06478	-32.816600,116.379770	2024-02-11	2024-02-12	2	X	X	.	.	X	X	X	.
BB011	S4U06478	-32.816600,116.379770	2024-02-09	2024-02-10	2	X	X	.	.	X	X	X	X
BB012	S4U06484	-32.830550,116.357890	2024-02-11	2024-02-12	2	.	.	.	.	X	X	X	.
BB013	S4U11651	-22.114890,119.916880	2024-02-11	2024-02-12	2	X	.	X	X	X	X	X	.
BB014	644439	-22.209053,119.813850	2024-02-07	2024-02-08	2	.	.	.	.	X	.	X	.
BB015	S4U11658	-32.791420,116.382810	2024-02-09	2024-02-10	2	X	X	.	.	X	X	X	X
BB016	S4U11651	-22.114890,119.916880	2024-02-05	2024-02-06	2	X	X	X	.	X	X	.	X
BB017	644440	-22.231794,119.898666	2024-02-07	2024-02-08	2	X	X	.	.	X	X	X	.
BB019	636488	-22.175192,119.854073	2024-02-07	2024-02-08	2	X	X	.	.	X	X	.	X
BB020	S4U11651	-22.114890,119.916880	2024-02-07	2024-02-08	2	X	.	.	.	X	X	.	X
BB021	S4U11658	-32.791420,116.382810	2024-02-11	2024-02-12	2	X	.	X	.	X	X	X	.
BB022	S4U06478	-32.816600,116.379770	2024-02-07	2024-02-08	2	X	X	X	.	X	X	X	X
BB023	S4U06484	-32.830550,116.357890	2024-02-07	2024-02-08	2	X	X	.	.	X	X	X	X
BB024	S4U06484	-32.830550,116.357890	2024-02-05	2024-02-06	2	.	.	.	.	.	X	X	.

						<i>C. gouldii</i>	<i>C. jobensis</i>	<i>O. lumsdenae</i>	<i>R. aurantia</i>	<i>S. flaviventris</i>	<i>S. greyii</i>	<i>T. georgianus</i>	<i>V. finlaysoni</i>
Site	Detector serial	Coordinates	First night	Last night	Nights								
BB025	S4U11723	-32.911090,116.475810	2024-02-05	2024-02-06	2	X	X	X	.	X	X	X	X
BB026	S4U11657	-32.816600,116.379770	2024-02-05	2024-02-06	2	X	X	.	.	X	X	X	X
BB027	S4U06478	-32.816600,116.379770	2024-02-05	2024-02-06	2	X	.	.	.	.	X	X	.
BB028	S4U11658	-32.791420,116.382810	2024-02-05	2024-02-06	2	.	.	.	.	.	X	.	.
BB029	S4U11659	-32.781330,116.495450	2024-02-05	2024-02-06	2	X	X	X	.	X	X	X	.
BB030	636494	-22.011641,119.931221	2024-02-05	2024-02-06	2	X	.	.	.	X	.	X	.
BB031	636488	-22.015392,119.875801	2024-02-09	2024-02-10	2	X	.	.	.	X	.	X	.
BB032	644436	-22.145529,119.928078	2024-02-05	2024-02-06	2	X	.	.	.	.	X	.	.
BB033	644440	-21.964575,119.868095	2024-02-11	2024-02-12	2	X	.	.	.	X	X	.	X
BB034	S4U11651	-22.114890,119.916880	2024-02-09	2024-02-10	2	X	.	.	.	X	X	X	X
BB035	S4U06484	-32.830550,116.357890	2024-02-09	2024-02-10	2	X	X	.	.	X	X	X	.
BB036	644440	-22.033985,119.914337	2024-02-05	2024-02-06	2	X	X	.	.	X	X	X	X
BB037	644440	-22.045576,119.883087	2024-02-09	2024-02-10	2	X	.	.	.	X	.	X	.
BB038	636494	-22.209028,119.868584	2024-02-07	2024-02-08	2	X	X	.	.	X	X	X	X
BB039	S4U11659	-32.781330,116.495450	2024-02-11	2024-02-12	2	X	.	.	X	X	X	X	X
BB040	644439	-22.058601,119.935104	2024-02-05	2024-02-06	2	X	.	.	.	X	X	X	.

Table 7. Species detected at each site in March 2024 ('BB' sites; continued next page).

						<i>C. gouldii</i>	<i>C. jobensis</i>	<i>O. lumsdenae</i>	<i>R. aurantia</i>	<i>S. flaviventris</i>	<i>S. greyii</i>	<i>T. georgianus</i>	<i>V. finlaysoni</i>
Site	Detector serial	Coordinates	First night	Last night	Nights								
BB002	S4U11651	-22.112400,119.871900	2024-03-22	2024-03-23	2	.	.	.	.	X	.	X	.
BB004	644439	-21.949398,119.793747	2024-03-18	2024-03-19	2	X	.	.	.	X	X	X	X
BB006	S4U11657	-21.951290,119.792600	2024-03-21	2024-03-22	2	X	X	.	.	X	X	X	X
BB007	636488	-22.051115,119.825081	2024-03-18	2024-03-19	2	X	.	.	.	X	X	.	.
BB008	S4U11657	-21.951290,119.792600	2024-03-25	2024-03-26	2	X	.	.	.	X	.	X	X
BB009	S4U06478	-22.079100,119.814400	2024-03-25	2024-03-26	2	X	X	.	.	X	X	X	.
BB014	655145	-22.210754,119.813789	2024-03-23	.	1	.	.	.	.	X	.	.	.
BB015	S4U11659	-22.079630,119.814300	2024-03-21	2024-03-22	2	X	X	.	.	X	X	.	X
BB016	S4U11723	-22.199810,119.920150	2024-03-17	2024-03-19	3	X	X	X	.	X	X	X	.
BB017	S4U11723	-22.199810,119.920150	2024-03-20	2024-03-22	3	X	X	.	.	X	X	.	X
BB018	636473	-22.247828,119.842186	2024-03-23	2024-03-24	2	X	.	.	.	X	X	.	X
BB019	S4U11723	-22.199810,119.920150	2024-03-23	2024-03-24	2	X	X	.	.	X	X	X	.
BB021	S4U11651	-22.112400,119.871900	2024-03-24	2024-03-25	2	X	.	X	.	X	X	X	X
BB022	S4U06484	-22.102180,119.825030	2024-03-23	2024-03-24	2	X	X	.	.	X	X	.	X
BB023	644439	-21.975859,119.996063	2024-03-26	2024-03-27	2	X	X	X	.	X	X	.	.
BB024	S4U11651	-22.112400,119.871900	2024-03-26	2024-03-27	2	X	.	X	.	X	X	X	.
BB025	S4U11659	-22.079630,119.814300	2024-03-26	2024-03-27	2	X	.	X	.	X	X	.	.
BB026	636488	-21.906364,119.951920	2024-03-26	2024-03-27	2	X	X	X	.	X	X	X	.
BB027	S4U06484	-22.102180,119.825030	2024-03-26	2024-03-27	2	.	.	.	.	.	.	X	.
BB028	S4U11658	-21.919290,119.783830	2024-03-26	2024-03-27	2	X	X	.	.	.	X	X	.
BB029	S4U11657	-21.951290,119.792600	2024-03-23	2024-03-24	2	.	.	.	.	X	X	X	.
BB030	S4U11723	-22.199810,119.920150	2024-03-26	2024-03-27	2	X	.	X	.	X	X	X	X
BB031	S4U11658	-21.919290,119.783830	2024-03-21	2024-03-22	2	X	.	.	.	X	X	X	.
BB032	644439	-22.145163,119.928123	2024-03-21	2024-03-22	2	X	X	.	.	X	X	.	.

						<i>C. gouldii</i>	<i>C. jobensis</i>	<i>O. lumsdenae</i>	<i>R. aurantia</i>	<i>S. flaviventris</i>	<i>S. greyii</i>	<i>T. georgianus</i>	<i>V. finlaysoni</i>
Site	Detector serial	Coordinates	First night	Last night	Nights								
BB033	S4U11658	-21.919290,119.783830	2024-03-23	2024-03-24	2	.	.	.	.	.	.	.	.
BB034	S4U11659	-22.079630,119.814300	2024-03-23	2024-03-24	2	X	.	.	.	X	.	X	X
BB036	644439	-22.034061,119.914505	2024-03-23	2024-03-24	2	X	.	X	.	X	X	X	X
BB037	636488	-22.045712,119.883575	2024-03-23	2024-03-24	2	.	.	.	.	.	.	X	.
BB038	636472	-22.208471,119.869171	2024-03-23	2024-03-24	2	.	X	.	.	X	X	.	.
BB039	S4U06484	-22.102180,119.825030	2024-03-18	2024-03-19	2	X	.	.	.	X	X	.	X
BB040	S4U06478	-22.079100,119.814400	2024-03-23	2024-03-24	2	X	.	.	.	.	.	X	X

Table 8. Species detected at each site in March 2024 ('BDDP' sites).

						<i>C. gouldii</i>	<i>C. jobensis</i>	<i>O. lumsdenae</i>	<i>R. aurantia</i>	<i>S. flaviventris</i>	<i>S. greyii</i>	<i>T. georgianus</i>	<i>V. finlaysoni</i>
Site	Detector serial	Coordinates	First night	Last night	Nights								
BB003/BDDP16	S4U11658	-21.919290,119.783830	2024-03-18	2024-03-20	3	X	X	.	.	X	X	X	X
BDDP14	S4U11657	-21.951290,119.792600	2024-03-19	.	1	X	X	.	.	X	X	X	.
BDDP15	636494	-22.029480,119.826431	2024-03-18	2024-03-20	3	.	.	.	.	.	.	.	.
BDDP17	S4U11651	-22.112400,119.871900	2024-03-19	2024-03-21	3	.	X	.	.	X	.	X	.
BDDP18	636488	-21.893881,119.785057	2024-03-20	2024-03-22	3	X	.	.	.	X	X	X	X
BDDP19	S4U11659	-22.079630,119.814300	2024-03-17	2024-03-19	3	X	.	.	.	X	X	.	X
BDDP20	S4U06478	-22.079100,119.814400	2024-03-17	2024-03-19	3	X	X	.	.	X	X	X	X
BDDP22	S4U06478	-22.079100,119.814400	2024-03-20	2024-03-22	3	X	.	.	.	X	X	X	.
BDDP23	S4U11651	-22.112400,119.871900	2024-03-16	2024-03-18	3	X	.	.	.	X	X	X	X
DBOPP1	636472	-21.900614,119.884453	2024-03-26	2024-03-27	3	X	X	.	.	X	X	X	X

Table 9. Summary of analyses of the acoustic lure recordings (Chorus bat detector and two infrared camera traps per site).

Site	Chorus	Coordinates	Video timestamp
BDGB01	641036	-22.034065 119.914177	.
BDGB02	636474	-21.888155 119.781609	.
BDGB03	rec fail	.	18:52:22 and 18:52:54
BDGB04	641036	-22.100115 119.988914	.
BDGB05	636473	-21.905867 119.865448	.
BDGB06	641036	-21.975908 119.999283	.
BDGB07	636474	-21.915771 120.013268	.

Table 10. Summary of detections of the Pilbara Diamond-faced Bat from all sites (blue highlight aid inspection by separating sites; continued next page).

Site-unit	Night of	Passes	Sunset	Dusk	Dawn	Sunrise	Time of first detection	Time of last detection	Time since sunset	Time until sunrise
May 2023										
BBD01 MDSM4-02	27/05/2023	8	27/05/2023 17:25	27/05/2023 17:49	28/05/2023 6:07	28/05/2023 6:31	20:38:32	1:39:06	3H 13M 4S	4H 52M 50S
BBD02 MDSM4-03	28/05/2023	1	28/05/2023 17:25	28/05/2023 17:49	29/05/2023 6:08	29/05/2023 6:32	20:11:13	20:11:13	2H 45M 58S	10H 21M 9S
BBD06 MDSM4-07	30/05/2023	1	30/05/2023 17:24	30/05/2023 17:49	31/05/2023 6:09	31/05/2023 6:33	23:29:49	23:29:49	6H 4M 55S	7H 3M 25S
BDBAT01 MDSM4-06	28/05/2023	1	28/05/2023 17:25	28/05/2023 17:49	29/05/2023 6:08	29/05/2023 6:32	23:29:31	23:29:31	6H 4M 16S	7H 2M 51S
BDDP03 MDSM4-01	23/05/2023	1	23/05/2023 17:26	23/05/2023 17:50	24/05/2023 6:06	24/05/2023 6:30	23:25:59	23:25:59	5H 59M 32S	7H 4M 11S
BDDP06 MDSM4-05	26/05/2023	1	26/05/2023 17:25	26/05/2023 17:49	27/05/2023 6:07	27/05/2023 6:31	20:34:04	20:34:04	3H 8M 23S	9H 57M 26S
BDDP06 MDSM4-05	27/05/2023	9	27/05/2023 17:25	27/05/2023 17:49	28/05/2023 6:07	28/05/2023 6:31	19:53:28	2:01:34	2H 28M 0S	4H 30M 22S
BDDP06 MDSM4-05	28/05/2023	10	28/05/2023 17:25	28/05/2023 17:49	29/05/2023 6:08	29/05/2023 6:32	21:00:22	2:01:46	3H 35M 7S	4H 30M 36S
BDDP06 MDSM4-05	29/05/2023	21	29/05/2023 17:25	29/05/2023 17:49	30/05/2023 6:08	30/05/2023 6:32	21:13:34	1:23:40	3H 48M 30S	5H 9M 8S
BDDP07 MDSM4-04	27/05/2023	1	27/05/2023 17:25	27/05/2023 17:49	28/05/2023 6:07	28/05/2023 6:31	21:02:40	21:02:40	3H 37M 12S	9H 29M 16S
October 2023										
BDDP13 MDSM4-02	14/10/2023	1	14/10/2023 18:04	14/10/2023 18:26	15/10/2023 5:06	15/10/2023 5:29	0:21:28	0:21:28	6H 17M 24S	5H 8M 10S
BB011 MDSM4-03	16/10/2023	17	16/10/2023 18:04	16/10/2023 18:27	17/10/2023 5:05	17/10/2023 5:27	22:34:05	2:31:13	4H 29M 12S	2H 56M 42S
BB011 MDSM4-03	17/10/2023	6	17/10/2023 18:05	17/10/2023 18:28	18/10/2023 5:04	18/10/2023 5:27	21:36:50	1:45:44	3H 31M 32S	3H 41M 21S
BB036 MDSM4-07	13/10/2023	3	13/10/2023 18:03	13/10/2023 18:26	14/10/2023 5:07	14/10/2023 5:30	20:02:06	23:09:58	1H 58M 25S	6H 20M 32S

Site-unit	Night of	Passes	Sunset	Dusk	Dawn	Sunrise	Time of first detection	Time of last detection	Time since sunset	Time until sunrise
BB03 TC39-644439	15/10/2023	11	15/10/2023 18:04	15/10/2023 18:27	16/10/2023 5:05	16/10/2023 5:28	19:32:11	3:50:51	1H 27M 43S	1H 37M 55S
BB03 TC39-644439	16/10/2023	6	16/10/2023 18:04	16/10/2023 18:27	17/10/2023 5:05	17/10/2023 5:27	19:30:17	3:08:43	1H 25M 24S	2H 19M 12S
February 2024										
BB03	9/02/2024	1	9/02/2024 18:44	9/02/2024 19:08	10/02/2024 5:24	10/02/2024 5:47	20:30:37	20:30:37	1H 46M 0S	9H 17M 21S
BB13	11/02/2024	1	11/02/2024 18:43	11/02/2024 19:06	12/02/2024 5:25	12/02/2024 5:49	2:16:32	2:16:32	7H 32M 58S	3H 32M 38S
BB39	11/02/2024	2	11/02/2024 18:43	11/02/2024 19:06	12/02/2024 5:25	12/02/2024 5:49	3:04:05	3:04:27	8H 20M 31S	2H 44M 43S

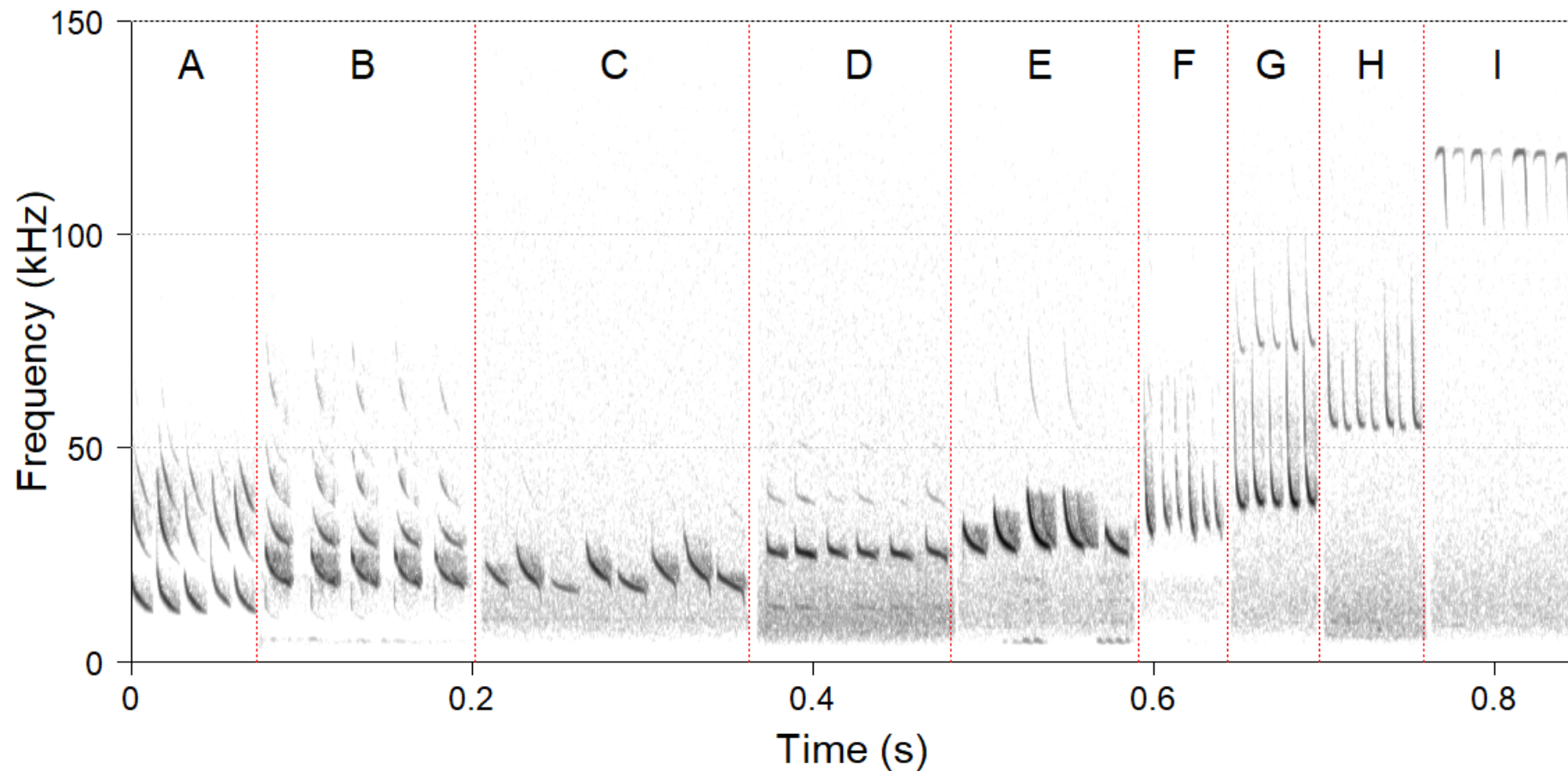


Figure 2. Representative echolocation call sequence portions of the species identified (**A:** *Austronomus australis*; **B:** *Saccolaimus flaviventris*; **C:** *Chaerephon jobensis*; **D:** *Taphozous georgianus*; **E:** *Ozimops lumsdenae*; **F:** *Chalinolobus gouldii*; **G:** *Scotorepens greyii*; **H:** *Vespadelus finlaysoni*; **I:** *Rhinonicteris aurantia*; time between pulses has been compressed).



Figure 3. Composite image of a 'fly-by' by one Ghost Bat at site BDGB03. No bat detector recordings were available from this site to confirm the observation, but the likelihood that this was a Ghost Bat is high (based on recognition of: anterior parts resembling long ears; the broadness of the wings, and lack of a distinct tail).



Figure 4. Examples of organisms that had features inconsistent with those of the Ghost Bat (**Top and middle:** Spotted Nightjar; **Bottom:** moth).

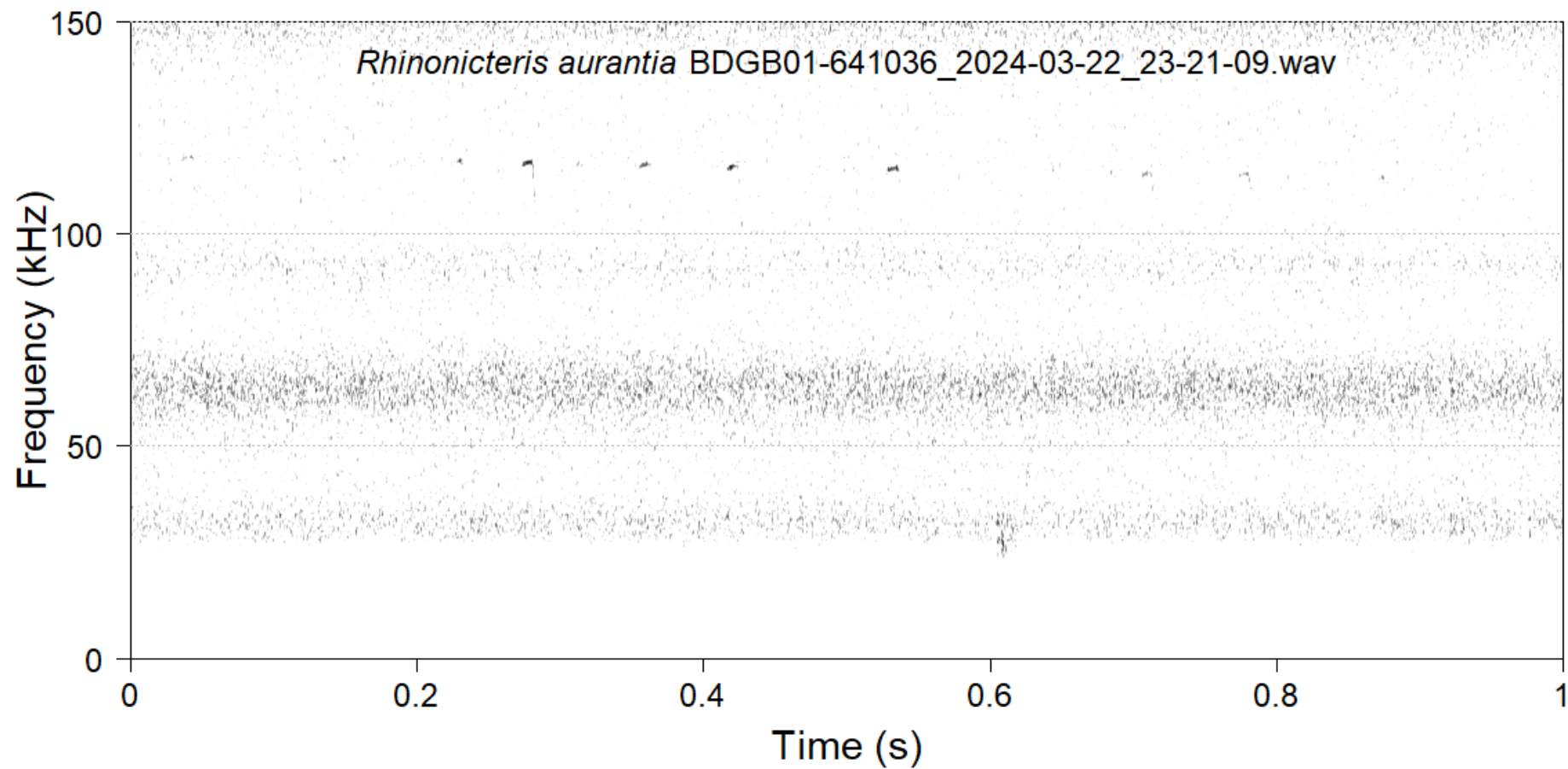


Figure 5. Representative echolocation call sequence portion of the Pilbara Diamond-faced Bat from acoustic lure site BDGB01.

Appendix 1. Summarising collision risk—a possible starting point

To understand the ‘collision risk’ of different bat Pilbara bat species, it might be useful to apply a modified generic risk matrix. I have provided a possible starting point for the development of a scheme in this appendix. In place of ‘Probability’ (rows), I have used the frequency of detection values calculated across all sites surveyed in 2023 – 2024, as sorted into four frequency ranges between 0 and 1; and in place of ‘Consequence’ (columns), I have used three likelihood categories of the species being present above 50 metres in altitude (turbine absent). The latter is an authoritative estimate based on my own accumulated casual field observations. The final score in the matrix is then divided into three risk categories. The final Risk Score and Collision Risk for each species is given in **Table A1**; and predictions for species not detected on the survey are given in **Table A2**. The Risk Scores and their Collision Risk categorisation seem to be sensible outcomes, though greater sampling effort for the Ghost Bat will give a more robust understanding of Collision Risk for this species.

		Likelihood of presence above 50 metres altitude		
Frequency of detection		Low	Medium	High
		1	2	3
0 – 0.25	1	1	2	3
0.25 – 0.50	2	2	4	6
0.50 – 0.75	3	3	6	9
0.75 – 1.0	4	4	8	12

Risk Score	Collision Risk
0 – 2	Low risk
3 – 6	Medium risk
7 – 12	High risk

Table A1. Calculated Risk Scores for each species based on the surveys in 2023 – 2024.

		High altitude likelihood	Altitude category	Frequency across all surveys	Frequency category	Risk Score	Collision Risk
MEGADERMATIDAE							
Ghost Bat	<i>Macroderma gigas</i>	Medium	2	0.14	1	2	Low
RHINONYCTERIDAE							
Pilbara Diamond-faced Bat	<i>Rhinonictis aurantia</i>	Low	1	0.10	1	1	Low
EMBALLONURIDAE							
Yellow-bellied Sheath-tailed Bat	<i>Saccolaimus flaviventris</i>	Medium	2	0.71	3	6	Medium
Common Sheath-tailed Bat	<i>Taphozous georgianus</i>	High	3	0.70	3	9	High
VESPERTILIONIDAE							
Gould's Wattled Bat	<i>Chalinolobus gouldii</i>	Low	1	0.85	4	4	Medium
Little Broad-nosed Bat	<i>Scotorepens greyii</i>	Low	1	0.85	4	4	Medium
Finlayson's Cave Bat	<i>Vespadelus finlaysoni</i>	Low	1	0.53	3	3	Medium
MOLOSSIDAE							
White-striped Free-tailed Bat	<i>Austronomus australis</i>	High	3	0.07	1	3	Medium
Greater Northern Free-tailed Bat	<i>Chaerephon jobensis</i>	Medium	2	0.55	3	6	Medium
Northern Free-tailed Bat	<i>Ozimops lumsdenae</i>	Medium	2	0.18	1	2	Low

Table A2. Predicted Risk Score and Collision Risk categories for Pilbara species of bat not observed on the survey (based on distributions given by Milne et al. 2023; 'estimated frequency' was 'imagined' based on records of occurrence in the Atlas of Living Australia).

		High altitude likelihood	'Estimated frequency'	Risk Score	Collision Risk
Black Flying-fox	<i>Pteropus alecto</i>	High	0.30	6	Medium
Little Red Flying-fox	<i>Pteropus scapulatus</i>	High	0.10	3	Medium
Hill's Sheath-tailed Bat	<i>Taphozous hilli</i>	High	0.20	3	Medium
Pallid Long-eared Bat	<i>Nyctophilus daedalus</i>	Low	0.10	1	Low
Lesser Long-eared Bat	<i>Nyctophilus geoffroyi</i>	Low	0.90	4	Medium
Northern Coastal Free-tailed Bat	<i>Ozimops cobourgianus</i>	Medium	0.00	0	Low

Appendix 2. Use of acoustic lures

Specialised Zoological provided the equipment for the acoustic lure surveys, and provided advice on how set and use it. The equipment and procedure are broadly consistent with recently released guidelines in the Northern Territory for the use of acoustic lures for Ghost Bat detection (Ruykys et al. 2024). In the Introduction to these guidelines, the authors state that “...it is expected that further application across the species’ distribution will improve its generality and functionality.”; (see also section 2.8). Given my own experience with the use of this method on several projects, and some practical considerations, I have provided advice in the present survey that I consider to be important improvements. These include:

1. The use of a bat detector directly under the portable speaker to detect the echolocation calls of a Ghost Bat that approaches and might briefly circle the post with this equipment. I address the five cautions articulated in the third ‘author’s tip’ in section 2.6 of the guidelines:
 - i. **“ghost bats do not consistently use echolocation when in flight”** Indeed Ghost Bats are thought not to echolocate continuously while in flight, but they are more likely to echolocate when approaching an object of their attention. In my own experience (not yet in the public domain; n = >20; exact number not given to preserve project anonymity), 74% of approaches could be validated unambiguously by the concurrent detection of an echolocation sequence on a bat detector placed under the speaker. For the remaining 26% of sites, it is possible that echolocation calls were not detected because of a combination of the low amplitude of the calls and the direction of flight relative to the zone of sound reception of the microphone.
 - ii. **“the acoustic lure may mask any echolocation pulses from ghost bats”** This is not the case. No echolocation calls are part of the broadcast sequence used. Further, echolocation pulses are of a different frequency range than the various social calls, and overlapping of broadcast social calls and the echolocation calls of an approaching bat does not prevent them from being distinguished, either by casual observation in a spectrogram, or the semi-automated analysis method used by Specialised Zoological.
 - iii. **“no ghost bats were detected acoustically during the study by Ruykys et al. (2023), despite ghost bats routinely flying with 1 m of bat detectors”** In that study, bat detectors were not placed in an ideal position (see underlined segments) for recording echolocation calls, and consequently the usefulness of bat detectors is under-emphasised in the guidelines:

“To determine whether the echolocation calls of lured ghost bats could be passively detected, a bat detector (Anabat Swift, Titley Scientific, Queensland, Australia) was deployed on the reference tree at each survey site for both the control and active treatment. Detectors were deployed at chest height, with the ultrasonic omnidirectional microphone placed on the far side of the tree, away from the speaker. The microphone was angled at 45° down from vertical.” (Ruykys et al. 2023; my underline)

- iv. **“expertise is required to identify bats – particularly ghost bats – via their echolocation call”** Specialised Zoological has a long track record of being able to identify these calls reliably, using an efficient semi-automated method, and being able to distinguish them from signals of similar shape produced by other cave-roosting bat species.
- v. **“the analysis of acoustic recordings will add significant analysis time to a project”** The analysis of bat detector recordings from acoustic lure sites using Specialised Zoological’s semi-automated method is efficient, requiring relatively little time for analysis, and certainly far less than a full manual inspection of the dataset. Most importantly, a validation of observations from videos from an independent, unambiguous identification based on diagnostic echolocation calls is extremely valuable. While some visitations of Ghost Bats might be very clearly of this species in the videos, there can be uncertainty with others. Echolocation call detection provides adequate validation.

In addition, there is comment in the guidelines about the difficulty of recognising juvenile Ghost Bats in videos, and consequently a recommendation to avoid using the technique when juveniles are likely to be present (section 2.3.1; p. 15). This is unnecessary because juveniles can also be recognised by echolocation calls in the same way as adults.

2. Much detail is given in the guidelines about the density of sampling and the probability of detection—especially for a ‘first stage’ survey (see section 2). But it should be noted that probability of detection is likely to be different in other landscapes, given the number of nearby roosts, and the colony size in those roosts. In addition, the effective broadcast range of the acoustic lure is relatively limited, and has not yet been properly estimated (or standardised), though a diameter of 200 metres seems reasonable. The size of this stimulus zone might be too small for some situations, especially where different habitats and landscape features might need to be investigated to address specific requirements. Thus, increased sampling density consistent with the notion of the ‘second stage’ survey might be required for questions such as *‘Which habitats do Ghost Bats use in this study area?’* or *‘Do Ghost Bats visit this feature?’* The notion of the appropriate sampling density for different regions and study objectives is deserving of more discussion. This is acknowledged in section 2.8 of the guidelines.
3. Further empirical observations will provide a better understanding of the potential impact of the technique on the Ghost Bat, which will either support or diminish concern for the various ethical considerations mentioned throughout the guidelines. In my own experience in one comprehensive study, visitations typically involved either a single pass of the speaker, or else presence of a few seconds only, and typically less than one minute. Key to understanding impacts is knowing how many individuals might be detected (this information cannot be determined), the total visitation time, number of visitations per night, associated behaviours, and whether a roost site is likely to be nearby (relevant for the time when broadcasts are started). At present, I have recommended that broadcasts continue for longer than is recommended in the guidelines because the aim is to maximise the chance of detection in relatively large,

complex geological terrains. In my experience, the time of first detection of a Ghost Bat can be anytime throughout the night, though certainly most detections are within the first 2 – 3 hours after sunset.

4. The equipment described and illustrated in the guidelines comprises a single video camera. I recommend two 4K video cameras placed at right angles so that a second view of any approaching bat is available for situations where an identification is ambiguous. It also provides redundancy in case of equipment set-up issues, given the high cost of remote field surveys. I also recommend speakers that play from a micro-SD card rather than Bluetooth. The equipment set-up used on the present survey has been used successfully elsewhere, though it has several constraints, and the system will likely keep evolving with experience, feedback and the availability of newer technology.
5. In the guidelines there is an emphasis on the manual review of video streams and how this should be undertaken. The semi-automated analysis conducted by Specialised Zoological represents a significant improvement over manual reviews, and is undertaken with a different set of considerations designed to maximise robustness. Most of the information in section 2.6 on page 20 is not relevant to the present study.
6. I consider that effort for the discovery of diurnal roost sites is still the primary consideration for environmental impact assessments, but that the acoustic lure method is useful for confirming presence both near roosts and away from them, and for characterising the use of a study area for foraging.
7. Specialised Zoological has had minimal input into the sampling design and level of sampling intensity in this study.

This study used squabble calls provided by Dr Nicola Hanrahan with permission. I have confirmed with her that no registration number is required for this project because it began before the guidelines were released.

8.3 Appendix C. Specialised Zoological report 2025



**Identification of bat species
from Bonney Downs, Western Australia:
October 2023 – August 2025**

Prepared for **Ecologia Environment Pty Ltd**

Version **1 December 2025**

SZ project reference **SZ761**

Specialised Zoological ABN 92 265 437 422

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This report should be included as an appendix in any larger submission to Government, and cited as:

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Version history

Date	Note
2025-12-01	Final version

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Summary

Bat identifications from bat detector sound files are provided from recordings made between October 2023 and August 2025 in the Bonney Downs project area in the Pilbara region of Western Australia (see also Specialised Zoological 2024, 2025).

The scope of the analysis extended to the identification of all bat species present, but with particular attention given to the detection of species of conservation significance: Ghost Bat *Macroderma gigas* (Megadermatidae) and Pilbara Leaf-nosed Bat *Rhinonycteris aurantia* (Rhinonycteridae). Note that the Ghost Bat was targeted with acoustic lures (method follows Hanrahan et al. 2023; Ruykys et al. 2023, 2024), and the present report does not include those outcomes.

The dataset submitted for analysis comprised a total of 966,446 full spectrum WAV-format sound files recorded from eight surveys at up to 40 standardised recording positions over a total of 586 survey nights (mostly two nights per site) for the period October 2023 to August 2025 (**Table 1**). In addition, results from other sites in the project area were reported in Specialised Zoological (2024).

Ten species of bat were identified as being present (**Tables 2 and 3; Figure 1**).

The Ghost Bat was not detected in these recordings.

The Pilbara Leaf-nosed Bat was detected at 17 sites across a total of 25 sampling nights (**Table 1**). The times of detection were well after sunset and well before dawn, which is indicative of individuals foraging away from a diurnal roost.

A brief summary of Collision Risk was derived using a novel risk matrix developed for Pilbara bats by Specialised Zoological, the overall Frequency of Detection values calculated across the eight surveys, and an authoritative estimate of the relative probability that a bat species could be detected above 50 metres in altitude (**Appendix A**).

Only a summary of the identifications is presented in this report (Frequency of Detection—the proportion of sampling sites where each species was detected), with the detail presented in an accompanying spreadsheet [SZ761_master20251130.xlsx](#)

Methods

The ultrasonic recordings provided were recorded in WAV format with Wildlife Acoustics SM4BAT-FS bat detectors (sampling rate 384 kHz) and Titley Scientific Anabat Chorus bat detectors (sampling rate 500 kHz), both set for automated triggered recordings between sunset and sunrise.

A multi-step acoustic analysis procedure developed to process large full spectrum echolocation recording datasets from insectivorous bats (Armstrong et al. 2021a,b) was applied to the recordings made on the survey. Firstly, the WAV files were scanned for bat echolocation calls using several parameter sets in the software SCAN'R version 1.8.3 (Binary Acoustic Technology), which also provides measurements (SCAN'R parameters) from each putative bat pulse. The outputs were then used to determine if putative bat pulses measured in SCAN'R could be identified to species. This was done using a custom [R] language application that performed three tasks:

1. undertook a Discriminant Function Analysis on training data from representative calls from Pilbara bat species;
2. from the measurements of each putative bat pulse from SCAN'R, calculated values for the first two Discriminant Functions that could separate the echolocation call types derived from the analysis of training data, and plotted these resulting coordinates over data ellipses representing one standard deviation of the variation for the defined call types; and
3. facilitated an inspection in a spectrogram of multiple examples of each call type for each recording night by opening the original WAV files containing pulses of interest in ADOBE AUDITION version 25.0.

Species were identified based on information in the author's unpublished material and Churchill (2008). Nomenclature follows Jackson and Groves (2015). Identifications were supported by distribution information in a curated source of distribution records maintained by the Australasian Bat Society, Inc. (<https://www.ausbats.org.au/batmap.html>) (Milne et al. 2023). Custom [R] language scripts were used to summarise the analysis outcomes.

Limitations and constraints

The identifications presented in this report have been made within the following context:

1. The identifications made herein were based on the ultrasonic acoustic data recorded and provided by a 'third party' (the client named on the front of this report).
2. The scope of this report extended to providing information on the identification of bat species in bulk ultrasonic recordings. Further comment on these species and the possible impacts of a planned project on bat species were not part of the scope.
3. In the case of the present report, the recording equipment was not set up for this survey by Specialised Zoological. The equipment was operated by the third party during the survey.
4. Other than the general location of the study area, Specialised Zoological has not been provided with detailed information of the survey area, has not made a visit to observe the habitats available for bats, nor have we visited the specific project areas on a previous occasion.
5. Specialised Zoological has had no input into the overall design and timing of this bat survey, recording site placement, nor the degree of recording site replication.
6. While identifications have been made to the best of our ability given the available materials, Specialised Zoological reserves the right to re-examine the data and revise any identification following a query, and it is the client's and / or proponent's responsibility to provide supporting evidence for any identification, which might require follow-up trapping effort or non-invasive methods such as video recordings. Specialised Zoological bears no liability for any follow-up work that may be required to support an identification based initially on the analysis of acoustic recordings undertaken and reported on here.
7. There are a variety of factors that affect the 'detectability' of each bat species, given the frequency, power and shape characteristics of their calls. Further information on the analysis and the various factors that can impinge on the reliability of identifications can be provided upon request.
8. The analysis of ultrasonic recordings is one of several methods that can be used to survey for bats, and comprehensive surveys typically employ more than one method. If an identification in the present report is ambiguous or in question, a trapping programme would help to resolve the presence of the possibilities in the project area.
9. The most reliable way of detecting the Ghost Bat *Macroderma gigas* with bat detectors is to place the equipment with the microphone facing into a potential cave roosting site. The echolocation calls of this species are of low amplitude, and therefore most detectable when a ghost bat flies close to the bat detector as it exits the underground structure. The detection of ghost bats with bat detectors away from cave entrances is less reliable, unless an approach based on an acoustic lure is used (Ruykys et al. 2023, 2024; Hanrahan et al. 2023). These results are reported elsewhere (including in Specialised Zoological 2024).
10. This version of the document supersedes any previous version. Previous drafts and interim reports are not authorised by us for submission to the regulator or the public domain.

References

- Armstrong K.N., Broken-Brow J., Hoyer G., Ford G., Thomas M. and Corben C. (2021a). Effective detection and identification of sheath-tailed bats of Australian forests and woodlands. *Australian Journal of Zoology* 68:346–363. <https://doi.org/10.1071/ZO20044>
- Armstrong K.N., Clarke S., Linke A., Scanlon A., Roetman P., Hitch, A.T. and Donnellan S.C. (2021b). Citizen science implements the first intensive acoustics-based survey of insectivorous bat species across the Murray-Darling Basin of South Australia. *Australian Journal of Zoology* 68: 364–381. <https://doi.org/10.1071/ZO20051>
- Churchill, S.K. (2008). *Australian bats*. 2nd ed. Allen and Unwin, Crows Nest, NSW.
- Hanrahan, N., Turbill C., Armstrong K.N., Dalziel A.H. and Welbergen J.A. (2023). Calling up ghosts: acoustic playback of social vocalisations reveals complex communication in a cryptic bat and provides a promising tool for monitoring disturbance-sensitive species. *Mammal Research*. <https://doi.org/10.1007/s13364-023-00727-w>
- Jackson, S.M. and Groves, C.P. (2015). *Taxonomy of Australian mammals*. CSIRO Publishing, Victoria.
- Milne D.J., Reardon T.B. and Ford G. (2023) BatMap – authoritative distribution maps for Australian bats. *Australian Mammalogy*. 45: 350–355. <https://doi.org/10.1071/AM23005>
- Ruykys, L., Hanrahan, N. and Stokeld, D. (2023). Novel acoustic lure methodology facilitates detection of the cryptic ghost bat at a landscape scale. *Wildlife Research* 51. <https://doi.org/10.1071/WR22189>
- Ruykys L., Hanrahan N. and Stokeld D. (2024) Northern Territory guidelines for surveying for the ghost bat at the landscape scale. Technical Report 05/2024, Department of Environment, Parks and Water Security, Palmerston, Northern Territory and Charles Darwin University, Brinkin, Northern Territory.
- Specialised Zoological (2024). Identification of bat species from Bonney Downs, Western Australia. Unpublished report by Specialised Zoological for Ecologia Environment Pty Ltd, version 2024-08-22, project reference SZ720.
- Specialised Zoological (2025). Identification of bat species from Bonney Downs, Western Australia. Unpublished report by Specialised Zoological for Ecologia Environment Pty Ltd, version 2025-02-22, project reference SZ756.

Table 1. Summary of recordings made over all surveys (Ra—Pilbara Leaf-nosed Bat; asterisk indicates that the numbers presented include only those that had data available for analysis).

Survey	Period	WAVs	Sites*	Nights	Sites with Ra	Nights with Ra
1	October 2023	121,987	42	80	4	6
2	February 2024	104,101	39	78	3	3
3	March 2024	65,952	31	63	0	0
4	June 2024	82,632	40	86	1	2
5	September 2024	192,397	37	74	1	2
6	February 2025	182,468	33	68	0	0
7	May 2025	139,817	31	62	6	8
8	August 2025	77,092	37	76	2	4
Totals	8	966,446	290	587	17	25

Table 2. Species identified in the present survey from all sites combined (* possibilities include the Lesser Long-eared Bat *N. geoffroyi* and Pallid Long-eared Bat *N. daedalus*).

RHINONYCTERIDAE	
Pilbara Leaf-nosed Bat (Pilbara Diamond-faced Bat)	<i>Rhinonictoris aurantia</i>
EMBALLONURIDAE	
Yellow-bellied Sheath-tailed Bat	<i>Saccolaimus flaviventris</i>
Common Sheath-tailed Bat	<i>Taphozous georgianus</i>
VESPERTILIONIDAE	
Gould's Wattled Bat	<i>Chalinolobus gouldii</i>
Unidentified long-eared bat*	<i>Nyctophilus</i> sp.
Little Broad-nosed Bat	<i>Scotorepens greyii</i>
Finlayson's Cave Bat	<i>Vespadelus finlaysoni</i>
MOLOSSIDAE	
White-striped Free-tailed Bat	<i>Austronomus australis</i>
Greater Northern Free-tailed Bat	<i>Chaerephon jobensis</i>
Northern Free-tailed Bat	<i>Ozimops lumsdenae</i>

Table 3. Frequency of Detection (summed over sites) across all surveys (see *Table A1* for the overall values of Frequency Detection across the entire survey programme).

Species	Oct2023	Feb2024	Mar2024	Jun2024	Sep2024	Feb2025	May2025	Aug2025	Key
<i>A. australis</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.05	0.1
<i>C. gouldii</i>	0.74	0.87	0.77	0.83	0.73	0.91	0.97	0.86	0.2
<i>C. jobensis</i>	0.45	0.54	0.39	0.60	0.27	0.36	0.65	0.41	0.3
<i>Nyctophilus</i> sp.	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.03	0.4
<i>O. lumsdenae</i>	0.14	0.18	0.26	0.03	0.11	0.39	0.32	0.14	0.5
<i>R. aurantia</i>	0.10	0.08	0.00	0.03	0.03	0.00	0.19	0.05	0.6
<i>S. flaviventris</i>	0.48	0.87	0.84	0.15	0.68	0.82	0.55	0.43	0.7
<i>S. greyii</i>	0.79	0.87	0.74	0.30	0.76	0.94	0.65	0.76	0.8
<i>T. georgianus</i>	0.50	0.77	0.61	0.50	0.35	0.67	0.77	0.65	0.9
<i>V. finlaysoni</i>	0.55	0.49	0.42	0.25	0.54	0.52	0.87	0.86	1

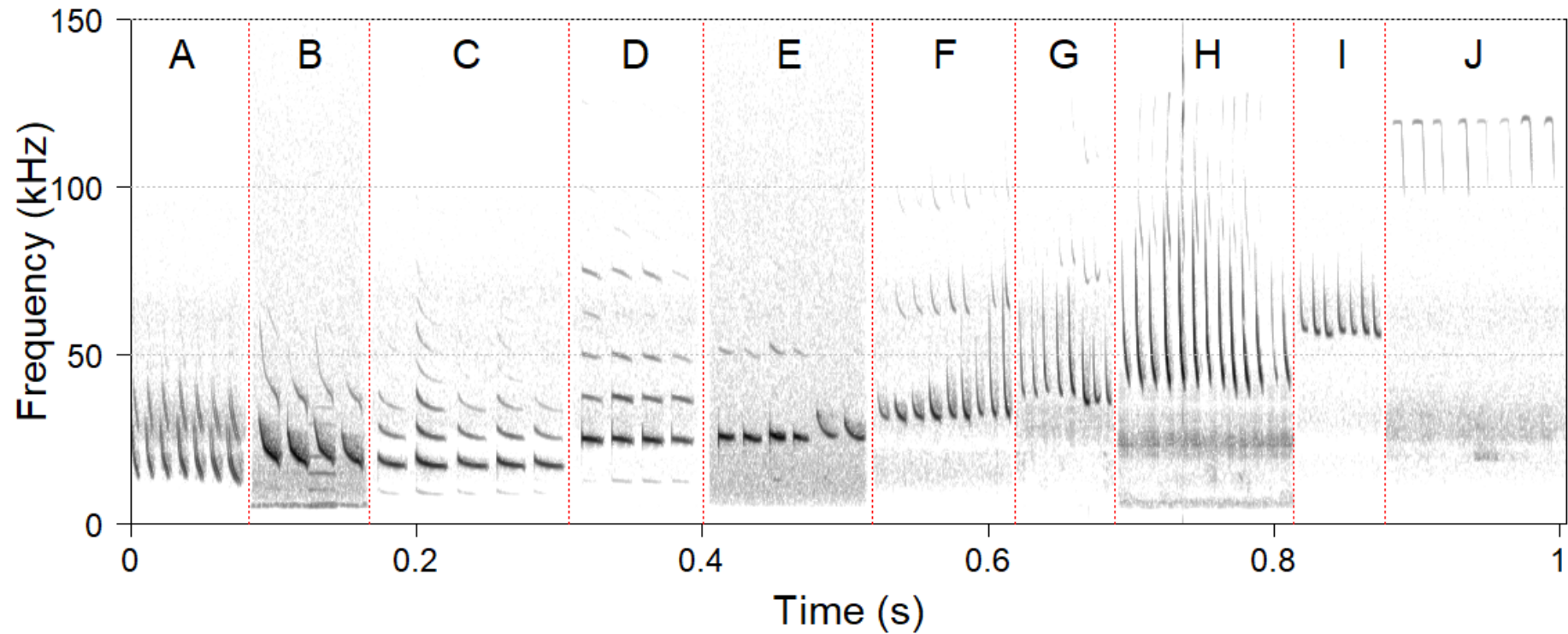


Figure 1. Representative echolocation call sequence portions of the species identified (**A:** *Austronomus australis*; **B:** *Chaerephon jobensis*; **C:** *Saccolaimus flaviventris*; **D:** *Taphozous georgianus*; **E:** *Ozimops lumsdenae*; **F:** *Chalinolobus gouldii*; **G:** *Scotorepens greyii*; **H:** *Nyctophilus* sp.; **I:** *Vespadelus finlaysoni*; **J:** *Rhinonictis aurantia*; time between pulses has been compressed).

Appendix 1. Summarising Collision Risk based on Frequency of Detection in the project area

To understand the 'Collision Risk' of different bat Pilbara bat species, it is useful to apply a modified generic risk matrix. I have provided a starting point for the development of a scheme in this appendix. In place of 'Probability' (rows), I have used the Frequency of Detection values calculated across all sites surveyed in 2023 – 2025, as sorted into four frequency ranges between 0 and 1; and in place of 'Consequence' (columns), I have used three likelihood categories of the species being present above 50 metres in altitude (turbine absent). The latter is an authoritative estimate based on my own accumulated casual field observations. The final score in the matrix is then divided into three risk categories. The final Risk Score and Collision Risk for each species is given in **Table A1**.

		Likelihood of presence above 50 metres altitude		
Frequency of Detection		Low	Medium	High
		1	2	3
0 – 0.25	1	1	2	3
0.25 – 0.50	2	2	4	6
0.50 – 0.75	3	3	6	9
0.75 – 1.0	4	4	8	12

Risk Score	Collision Risk
7 – 12	High risk
3 – 6	Medium risk
0 – 2	Low risk

Table A1. Calculated Risk Scores for each species based on the surveys in June and September 2024.

		High altitude likelihood	Altitude category	Frequency across all surveys	Frequency category	Risk Score	Collision Risk
RHINONYCTERIDAE							
Pilbara Leaf-nosed Bat	<i>Rhinioncteris aurantia</i>	Low	1	0.08	1	1	Low
EMBALLONURIDAE							
Yellow-bellied Sheath-tailed Bat	<i>Saccolaimus flaviventris</i>	Medium	2	0.59	3	6	Medium
Common Sheath-tailed Bat	<i>Taphozous georgianus</i>	High	3	0.69	3	9	High
VESPERTILIONIDAE							
Gould's Wattled Bat	<i>Chalinolobus gouldii</i>	Low	1	0.91	4	4	Medium
Unidentified long-eared bat	<i>Nyctophilus</i> sp.	Low	1	0.04	1	1	Low
Little Broad-nosed Bat	<i>Scotorepens greyii</i>	Low	1	0.78	4	4	Medium
Finlayson's Cave Bat	<i>Vespadelus finlaysoni</i>	Low	1	0.75	4	4	Medium
MOLOSSIDAE							
White-striped Free-tailed Bat	<i>Austronomus australis</i>	High	3	0.13	1	3	Medium
Greater Northern Free-tailed Bat	<i>Chaerephon jobensis</i>	Medium	2	0.47	2	4	Medium
Northern Free-tailed Bat	<i>Ozimops lumsdenae</i>	Medium	2	0.28	2	4	Medium

8.4 Appendix D. Records for other bat species

Two Vespertilionidae species represent some of the smallest species: Finlayson's cave bat *Vespadelus finlaysoni* (4.3 g), and Little broad-nosed bat *Scotorepens greyii* (6.4 g). These small bats have the lowest wing loading and wing aspect ratios (**Figure 8**) and the highest frequency echolocation calls (**Figure 4**). Bats with lower wing loading and wing aspect ratios exhibit higher manoeuvrability (Schunk *et al.* 2017), and their high frequency echolocation signal does not carry far but gives the greatest resolution against vegetation clutter. Together, their wing morphology and echolocation frequencies suit them to foraging against and amongst open vegetation. A third Vespertilionidae Gould's wattled bat *Chalinolobus gouldii* (9.8 g) is a high flying, open-air forager and a common fatality at older wind farms with low RSA (Hull & Cawthen 2013).

Three larger Molossid species were recorded: Northern free-tailed bat *Ozimops lumsdenae* (12.2 g), Greater northern free-tailed bat *Chaerephon jobensis* (20.4 g), and the much less commonly recorded, White-striped free-tailed bat *Austronomus australis* (37.6 g). These molossid bats have high wing loading and high wing aspect ratio (**Figure 8**) and the lowest frequency echolocation calls (**Figure 4**). Bats with high aspect ratio wings have superior lift-to-drag ratios and are therefore predicted to be able to fly faster or to sustain longer flights (Schunk *et al.* 2017). These bats are well-suited to open air foraging. They would have a HIGH likelihood of flying at foraging heights that would put them within the RSA (100–300 m).

Two sheath-tailed bats (Emballonuridae) were also recorded: Common sheath-tailed bat *Taphozous georgianus* (26.2 g) and Yellow-bellied sheath-tailed bat *Saccolaimus flaviventris* (44 g). These large bats are also open-air foragers that will fly at heights likely to be within the RSA.

There are no available wind farm mortality data for Finlayson's cave bat *Vespadelus finlaysoni*, Common sheath-tailed bat *Taphozous georgianus*, Northern free-tailed bat *Ozimops lumsdenae*, Greater northern free-tailed bat *Chaerephon jobensis*, or Leaf-nosed bat *Rhinonictis aurantia*, as their geographic ranges do not overlap operational wind farms (**Figure D1**).

Four of the bat species present at Bonney Downs are known to roost in caves (*Vespadelus finlaysoni*, *Rhinonictis aurantia*, *Taphozous georgianus*, and *Macroderma gigas*). Call activity for these species tended to increase during the night (**Figure 6**).

- Finlayson's cave bat *Vespadelus finlaysoni* (edge⁶ foraging) made up 19% of acoustic records. There was some evidence of seasonal patterns in activity, with most records collected during spring and winter. Activity appeared greatest during the middle of the night in spring (**Figure 6**). These tiny (~4 g) bats forage in small groups near their roosts in woodlands, grasslands, and use crevices/mines, with males and females sometimes separate. *Vespadelus finlaysoni* are able to utilise caves with a variety of microclimates (humidity and light levels) often using a variety of caves, disused mines and abandoned nests of fairy martins. Single colonies of more than 500 have been found, but they usually live in smaller colonies (Australian Museum 2025).
- Common sheath-tailed bat *Taphozous georgianus* (open⁷ foraging) made up 4% of acoustic records. Activity of these ~26 g bats was also greatest towards the middle of the night. The common sheath-tailed bat roosts in caves and boulder piles, but also in disused mines, especially where multiple entrances are available, and have a broad tolerance for a range of roost site humidity (Jolly 1990). There was indication of

⁶ Edge-foraging bats are insect-eating bats that hunt along the boundaries between different habitats (like forest edges, field margins, or waterways) because these 'edges' concentrate prey and offer navigation cues, acting as crucial foraging grounds and corridors for many aerial insectivores.

⁷ Open-foraging bats are large, fast-flying insectivores that hunt airborne insects in large, uncluttered spaces, using specialised echolocation for aerial hawking, differing from smaller bats that forage in dense foliage.

seasonal differences in activity, with greater numbers of records during summer than other months (**Figure 6**). Common sheath-tailed bat *Taphozous georgianus* is recognised as having HIGH collision risk under all three assessments (Specialised Zoological 2024, Voigt *et al.* 2024, Reid & Baker 2025, Specialised Zoological 2025).

The remaining six species generally make use of tree hollows for roost sites and are therefore less spatially restricted in their movements across the study site:

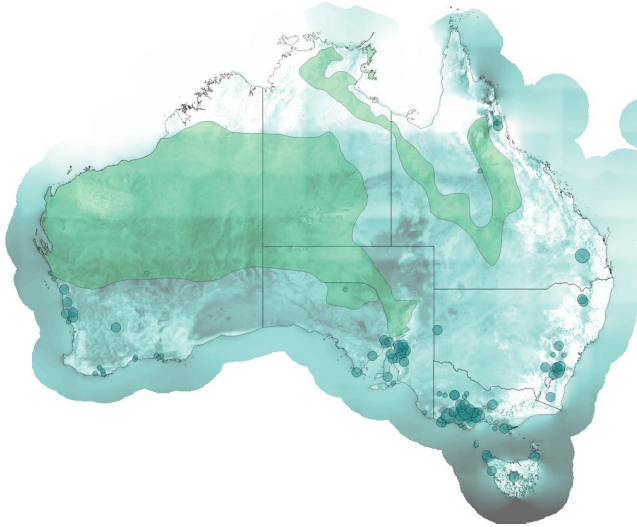
- Little broad-nosed bat *Scotorepens greyii* (open foraging) made up 11% of acoustic records. Species Distribution Modelling shows the whole study site as highly suitable habitat for this species (generally ~0.8/1 for suitability, Scarff & Shephard 2025). Their diet includes many flightless insects, suggesting that prey are gleaned from foliage. They are known to forage amongst treetops (but not above them) or over grassland, water and other open habitat. These small (~6 g) bats mostly roost in tree hollows, but also in hollow fence posts, under the caps of telegraph poles and in abandoned buildings, in groups of 2–20 (Churchill 2008a). Notably *Scotorepens greyii* was evident in largest numbers immediately after dusk (**Figure 6**), suggesting that these bats were using local resources for roosting. These bats are believed to have LOW likelihood of flying above 50 m (Specialised Zoological 2024) and therefore generally have low risk of turbine collision for an RSA of 100–300 m.
- Gould's wattled bat *Chalinolobus gouldii* (open foraging) was the most commonly recorded bat species at Bonney Downs, making up half (47%) of the acoustic records. These ~10 g bats have a broad geographic distribution across Australia and are one of the most common species recorded as wind turbine collisions (**Table 4**). They roost in tree hollows, forming colonies of 8–40 females (males are generally solitary), but roosting has also been recorded in buildings and amongst foliage (Churchill 2008). These bats change roosts daily, typically foraging 5–10 km from the roost site, more rarely 15 km away. Gould's wattled bat *Chalinolobus gouldii* is classified as LOW risk by and Specialised Zoological (2024), MEDIUM by Specialised Zoological (2025; this measure also accounting for high levels of activity at the site) and Reid and Baker (2025), and HIGH by Voigt *et al.* (2024). This species is a common fatality at wind farms (e.g., Hull & Cawthen 2013), making up about one third of all recorded collision mortalities (**Table 4**). This is likely due to this bat being the most widespread bat species in Australia, found in virtually all habitats across the continent, including urban areas, and being relatively common at wind farm sites.
- Northern free-tailed bat *Ozimops lumsdenae* (open foraging) made up only 1% of acoustic records, likely reflecting that of Bonney Downs represents acceptable but marginal-quality habitat for these bats (SDM habitat suitability ~0.1/1, with unsuitable parts of the station, Scarff & Shephard 2025). These ~12 g bats showed relatively high activity immediately on dusk (**Figure 6**), supporting their ability to make use of tree hollows but also other roosts such as house roofs. These Northern free-tailed bats are believed to have poor agility in the air, and prefer foraging in open spaces (Churchill 2008a). These bats are believed to have MEDIUM likelihood of flying above 50 m (Specialised Zoological 2024) and have been classed as MEDIUM collision risk (Reid & Baker 2025).
- Greater northern free-tailed bat *Chaerephon jobensis* (open foraging) made up 6% of acoustic records. These ~20 g bats hunt from high in the air to just above the tree canopy, or over grasslands and bare ground. There is little information available on how far away from the roost these bats will forage, but we note peak activity 2–3 hours after dusk and before dawn (**Figure 6**), suggesting that the bats may have travelled some distance. While Reid & Baker (2025) rate them as having HIGH collision likelihood, expert elicitation suggests that these bats have MEDIUM likelihood of flying above 50 m (Specialised Zoological 2024).
- Yellow-bellied sheath-tailed bat *Saccolaimus flaviventris* (open foraging) made up 12% of acoustic records. Much of Bonney Downs represents suitable habitat for these large ~38 g bats (SDM habitat suitability ~0.6/1, Scarff & Shephard 2025). There was evidence of seasonal patterns in activity, with greatest activity in spring at Bonney Downs (**Figure 6**). These bats range across all of northern Australia. Seasonal

movements are unknown, but there is speculation about a migration to southern Australia in late summer and autumn, with the bats migrating into south-eastern Australia as far as the Victorian south coast between January and April (NSW 2025). While Reid & Baker (2025) rate them as having HIGH collision likelihood, expert elicitation suggests that these bats have MEDIUM likelihood of flying above 50 m (Specialised Zoological 2024).

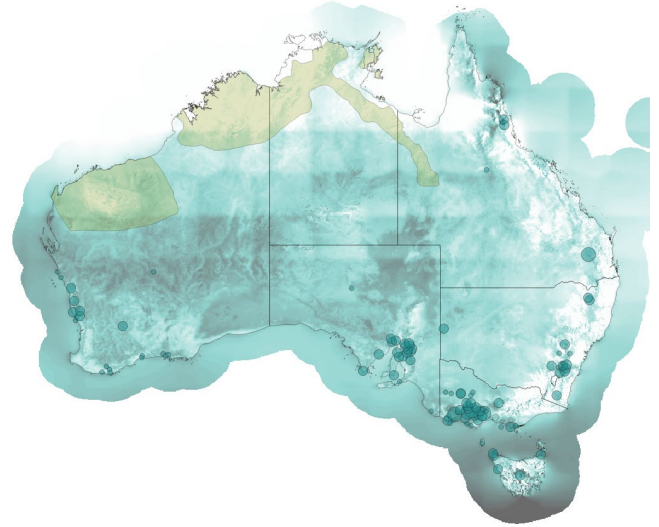
- Note that White-striped free-tailed bat *Austronomus australis* (open foraging) were only scarcely identified from ARU recordings during BBSUS (Specialised Zoological 2025). The white-striped freetail bat *Austronomus australis* is the most commonly reported bat fatality at Australian wind farms, making up almost two-thirds of reported bat deaths (62%, Symbolix data presented by Gration 2025). There are marked seasonal patterns of overall bat mortality for Victorian wind farms, with greater mortalities between January to April (Lentini *et al.* 2025a); two other consultant surveys found the same in Victoria but not in NSW (Lentini *et al.* 2025a), suggesting that these seasonal patterns may be site and species specific. The late summer/autumn fatalities (which are despite similar levels of activity) do not appear to be associated with juveniles learning to fly, nor pre-winter fattening leading to lower manoeuvrability (Lentini *et al.* 2025a). *Austronomus australis* migrate seasonally north-south, and they have been recorded at Bonney Downs (Specialised Zoological 2024). Collision risk is recognised as HIGH for this bat (Specialised Zoological 2024, Voigt *et al.* 2024, Reid & Baker 2025). However, this species has only scarcely been reported in the Pilbara (ALA records and data collected for BBSUS carried out at Bonney Downs), suggesting reduced risk for these high-flying, fast bats at Bonney Downs, as recognised by Specialised Zoological (2025) in attributing a MEDIUM risk category for this species.



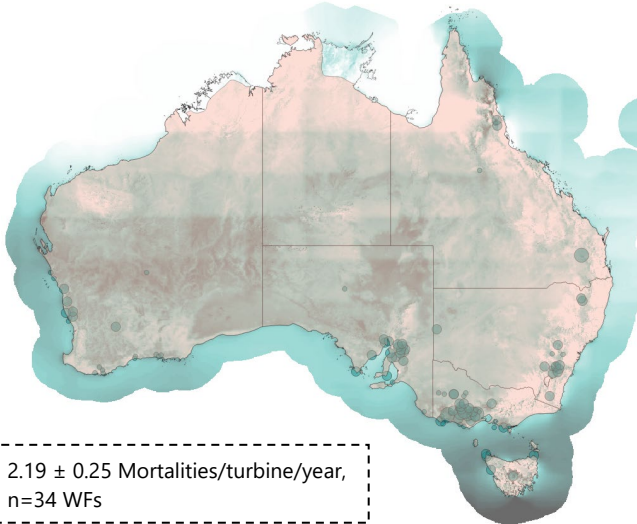
a. Finlayson's Cave Bat *Vespadelus finlaysoni* (576 ALA records; Stable) **LOW**[§]



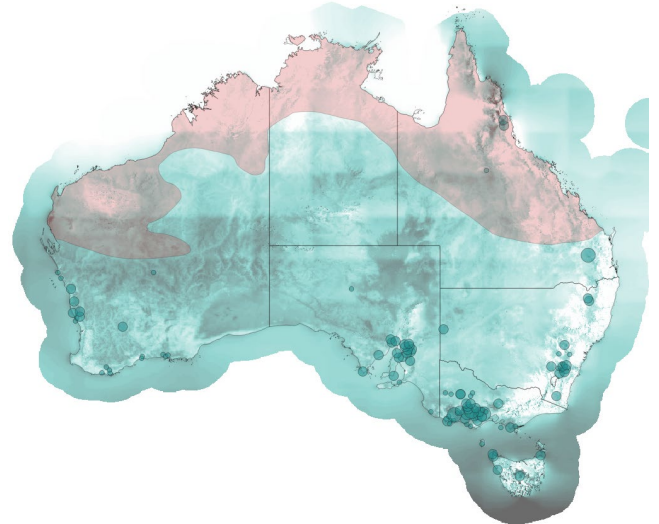
b. Common Sheath-tailed Bat *Taphozous georgianus* (273 ALA records; Stable) **HIGH**[§]



c. Gould's Wattled Bat *Chalinolobus gouldii* (138 ALA records; Stable) **LOW**[§]

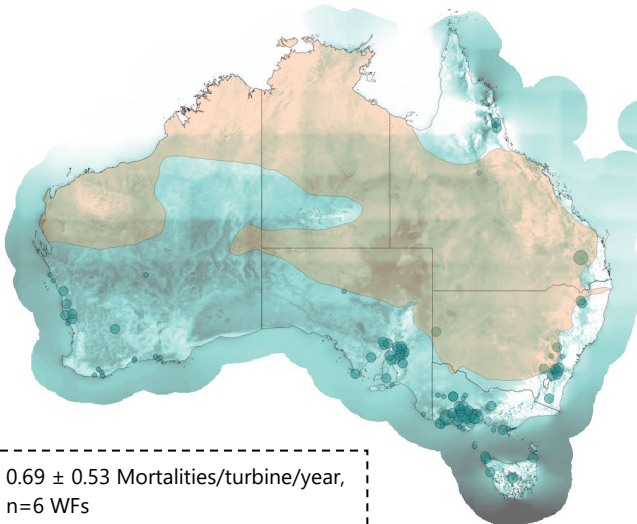


d. Greater Northern Free-tailed Bat *Chaerephon jobensis* (65 ALA records; Stable) **MEDIUM**[§]



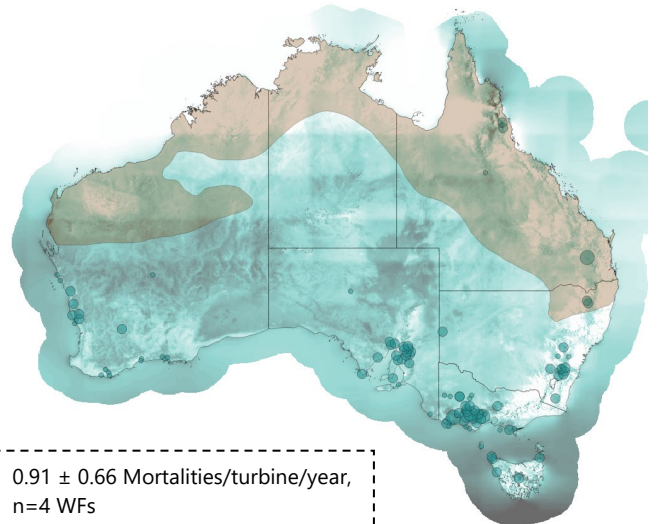
2.19 ± 0.25 Mortalities/turbine/year,
n=34 WFs

e. Little Broad-nosed Bat *Scotorepens greyii* (98 ALA records; Stable) **LOW**[§]



0.69 ± 0.53 Mortalities/turbine/year,
n=6 WFs

f. Northern Free-tailed Bat *Ozimops lumsdenae* (83 ALA records; Decreasing) **MEDIUM**[§]



0.91 ± 0.66 Mortalities/turbine/year,
n=4 WFs



g. Yellow-bellied Sheath-tailed Bat *Saccolaimus flaviventris* (12 ALA records; **Decreasing**) **MEDIUM**[§]

h. White-striped Free-tailed Bat *Austronomus australis* (5 ALA records; **Decreasing**) **HIGH**[§]

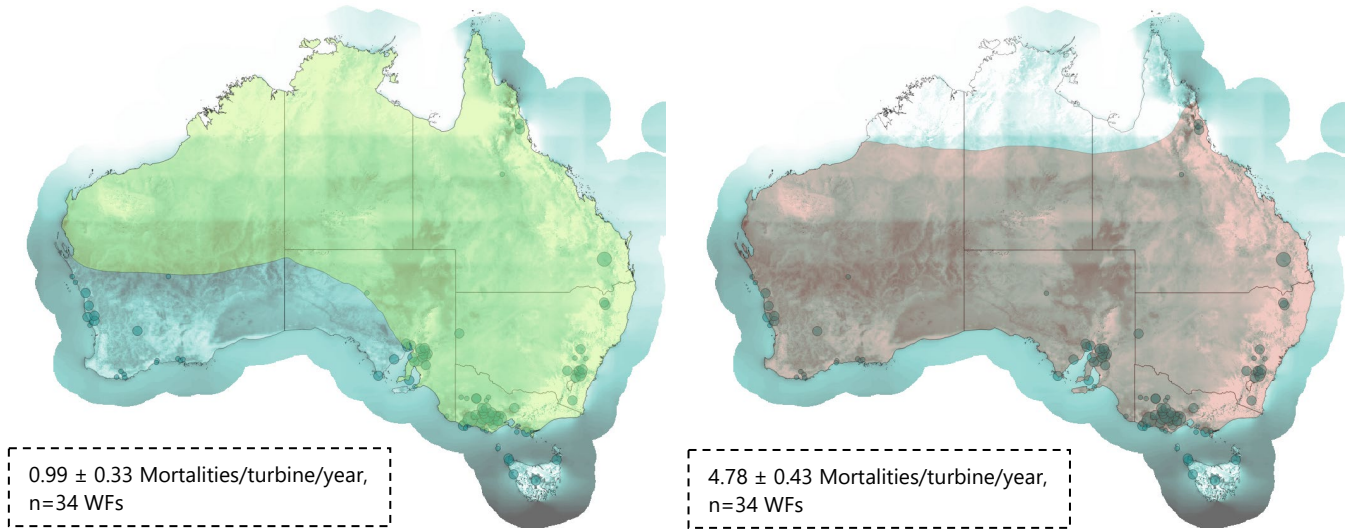


Figure D1. Overlap between species distribution maps (BatMap 2021, Milne et al. 2023), wind resources (green colour gradient) (Global Wind Atlas 2025) and operational wind farms (green circles; relative sizes reflect energy generation capacity) (Ecogeneration 2023) for 8 bat species recorded at Bonney Downs in the Pilbara. The numbers of ALA records and population status (stable, decreasing) are indicated. [§] Estimated risk scores for each bat species recorded in the 2023-2024 surveys at Bonney Downs, based on an authoritative estimate of which species are likely to be flying at >50 m in altitude (Specialised Zoological 2024, 2025). Mortality figures are unpublished data from (Gration 2025).