Bird and Bat Management Plan science for wind energy developments

Project 2.2.3 Collision Risk Modelling Outcomes Final Report

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Project 2.2.3 Collision Risk Modelling Outcomes

1 Executive summary

The Bonney Downs Generation Hub (BDGH) is proposed to be located at Bonney Downs Station in the Pilbara region of Western Australia. The proposed wind farm consists of up to 100 Wind Turbine Generators. A major concern is the potential impact on bird life due to the presence of large wind turbines; not only from the proposed BDGH but also the combined impact from the nearby Nullagine Pilot Wind Farm currently under development (17 turbines). An analysis of the combined risk to bird life via collision from both the proposed BDGH and the Nullagine Pilot Windfarm (total of 117 turbines) was performed.

A study of existing collision risk models (CRM) was undertaken. Data from the Bird and Bat Site Utilisation Surveys (BBSUS) conducted as part of this project (*ecologia* Environment 2025) and the Australian Database of Birds (BirdLife Australia 2025) were used in this project. Statistical modelling was used to cover missing data in flight height distribution (visual observations). Where possible, data from the two Robin Radar MAX units on site was analysed and prepared for use in the simulation models.

A publicly available CRM, the Band model (Band *et al.* 2007, Band 2012, Band 2024) was implemented. Additionally, a new 3D flight analysis model was developed especially for this project, mitigating identified shortcomings recognised for the Band model. The New Model uses a 3-dimensional approach to predict bird location and WTG interaction.

Simulations were run for 13 bird species that were observed at BDGH flying at heights that would be within the rotor sweep area (RSA) of the proposed WTGs. Using a conservative estimate of birds avoiding the WTG, results from the two models (Band Option 2 with 99.5% avoidance, New Model with 90% avoidance) were consistent and indicate relatively high (11.67%, 4.47%) collision risk for the Wedge-tailed eagle (with resident animals commonly recorded at the site), Australian pelican (2.77%, 5.25%), Straw-necked ibis (7%, 2.75%), Litte black cormorant (2.04%, 1.35%) and Masked woodswallow (2.19%, 1.55%). All other species were classified as having <2% collision risk. The Grey falcon (listed as Vulnerable **VU** under the IUCN, EPBC Act, and BC Act) was estimated to have a relatively low risk of collision under both models (1.86%, 1.6%).

It should be noted that the collision risk estimates presented below represent inherent (unmitigated) collision risk and do not account for the potential reduction achievable through management and design measures that may be adopted during project development or operations (e.g., curtailment, deterrent/monitoring systems, or blade marking/painting).

2 Key outcomes

- Both the Band and the New Model identified the same bird species at risk and at similar levels, providing verification of the methodology.

- The Band model has been calibrated over many years to improve consistency of results with field studies (fatality records). This calibration was obtained by comparing carcass numbers after the installation of the wind farm with predictions of the model (Urquhart, & Whitfield, 2016; Smales 2023), not with direct measurement or observation of birds avoiding the WTG (Hull & Muir 2013). The Band model therefore routinely uses high avoidance rates (99.5%). A 'worst-case' scenario was calculated using the Band model option 2 with 98% avoidance. By contrast, because it uses a three-dimensional approach, the New Model calculations predicted similar outcomes using lower numerical values for avoidance.

- The species with highest collision risk was identified as the Wedge-tailed eagle (11.67% for the Band Option 2 model with 99.5% avoidance rate, and 4.47% for the New Model with 90% avoidance rate). This raptor was commonly recorded at the site. This species also had the most BBSUS and radar records, and so the modelling estimates for flight height were most reliable.

- Straw-necked ibis (7.0%, 2.75%), Australian pelican (2.77%, 5.25%), Little black cormorant (2.04%, 1.35%) and Masked woodswallow (2.19%, 1.55%) were estimated as next in terms of collision likelihood.

- All other species were computed to have relatively low collision risk, with estimates <2% for both models.

- The Grey falcon (listed as a Vulnerable species) was identified as having predictions of 1.86% (Band Option 2) or 1.61% (New Model) of the population at risk of collision per year from the two models.

- Worst-case results with Band option 2 with 98% avoidance identified the same species as having higher rates of collision. The Straw-necked ibis and Wedge-tailed eagle stand out as having higher predicted collision risk than other species, with all other species at below 10%, even in this worst-case scenario.

Table 1. *Comparison of the predicted collision risk for 13 Pilbara bird species for the Band Model (Option 2 with 99.5% avoidance) and the New Model (assuming 90% avoidance). Cells are coloured from greatest (red) to least (green) collision risk. Bold values are >2%. Three further species were noted but insufficient data was available for CRM.*

Species		Nº of BBSUS records ǂ	**Band model 2** 99.5% Avoidance	**Band Model 2** 98% Avoidance 'Worst-case'	**New Model** 90% Avoidance
Australasian darter	*Anhinga novaehollandiae*	48	1.98	**5.46**	1.12
Australian kestrel	*Falco cenchroides*	250	0.44	1.18	0.57
Australian pelican	*Pelecanus conspicillatus*	4	**2.77**	**7.6**	**5.25**
Brown falcon	*Falco berigora*	91	1.44	**3.89**	1.52
Grey falcon **(VU)**	Falco hypoleucos	9	1.86	**5.05**	1.61
Little black cormorant	*Phalacrocorax sulcirostris*	113	**2.04**	**6.6**	1.35
Masked woodswallow	*Artamus personatus*	17	**2.19**	**6.03**	1.55
Spotted harrier	*Circus assimilis*	64	0.73	1.96	1.25
Straw-necked Ibis	*Threskiornis spinicollis*	33	**7**	**19**	**2.75**
Torresian crow	*Corvos orru*	86	0.01	0	0.03
Wedge tailed eagle	*Aquila audax*	133	**11.67**	**31.66**	**4.47**
Whistling kite	*Haliastur sphenurus*	90	1.75	**4.75**	1.98
White-necked heron	*Ardea pacifica*	27	0.55	1.49	1.2
Black-necked stork **(NT)**	*Ephippiorhynchus asiaticus*	2	Insufficient data		Insufficient data
Oriental plover **(MI)**	*Charadrius veredus*	1	Insufficient data		Insufficient data
Pacific swift **(MI)**	*Apus pacificus*	12	Insufficient data		Insufficient data

Conservation listings † *Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC) Act:* ***VU*** *Vulnerable,* ***MI*** *Migratory species protected under international agreement,* ***EN*** *Endangered. IUCN:* ***NT*** *Near Threatened. Others are not listed as conservation-significant.*

ǂ total across 480 hours of BBSUS observations.

Note that the collision risk estimates presented in this report represent ***'inherent (unmitigated) collision risk'*** *and do not account for the potential reduction achievable through management and design measures that may be adopted during project development or operations (e.g., curtailment, deterrent/monitoring systems, or blade marking/painting).*

3 Introduction

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, Fortescue are pursuing 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.

This project represents a collaboration between the Harry Butler Institute at Murdoch University (HBI) and Fortescue for Collision Risk Modelling (CRM) for species identified at potential risk of wind turbine collision at Bonney Downs Station (Bonney Downs Generation Hub and Nullagine Pilot Wind Farm), as per the Onshore Wind Farm Guidance (DAWE 2021, DCCEEW 2023b, 2024). This work recognises the need to identify effective mechanisms for mitigation of 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).

In what follows, we discuss the choice of birds for simulation, the data preparation, the Band model and the development of the New Model. Simulations were performed on 13 species, and the probability of a collision was computed for each.

3.1 Scope of work

This project has addressed six key aims (**Table 2**). The aims were identified in the original scope of work and the right-side column is the outcome for that aim.

Table 2. *Collision Risk Modelling Assessment Outcomes as proposed in the Scope of Works.*

Aim	Achievement
1. **Identify which species are most likely to be impacted by wind turbine strike** (based on presence, population size, location of their preferred habitat and therefore, predicted presence, flight height and characteristics).	Achieved. The results are as shown in **Tables 1 and 7**.
2. Where possible, **calculate collision risk windows** (i.e., the likelihood of collision) **for species or species groups of interest** dependent on flight height and/or 'style'. Collision risk windows are an important input parameter for CRM.	Achieved. Using the two models we obtained consistent results for those birds that were at risk of colliding with the WTG and the probability that such an event might occur given the flight speed and height. See **Sections 5 and 6.**
3. **Estimate worst case collision risk**, based on Band CRM (Band *et al.* 2007) "Worst-case" assumes a lower value for avoidance (birds diverting away from the WTG), but within the expected avoidance behaviour.	Achieved. This was completed using the Band model with 98% avoidance. Given the data available, all assumptions were made as general as possible, leading to worst-case scenarios. See **Sections 5 and 6.**
4. **Evaluate published CRMs** to determine which are useable prior to the wind farm construction phase. For example, a more sophisticated model may be possible if suitable data collected from an existing windfarm can be used to inform the model [e.g., Biosis modelling has been used in Wedge-tailed eagle and White-bellied sea-eagle (Smales *et al.* 2013) and Bayesian modelling in other raptor species (Adachi *et al.* 2015)], or where aerodynamic parameters can be derived through flight modelling.	Achieved. This was completed and is reported in **Section 4.1**
5. **Incorporation of site-specific environmental factors** (e.g., wind direction, velocity, temperature) within CRM for significant species with justification of the choice of the model used including a statement of all assumptions and uncertainties.	Achieved. Site specific data for bird behaviour was used, including measured wind speed and temperature. Wind speed is important in the turbine management and operational strategy.
6. **Inform CRM with actual flight behaviour of the species** (derived from radar traces, on-ground observations and other relevant data collected as part of stage 2.1), as well as relative abundance and significance of species (conservation listed, culturally significant or otherwise).	Achieved. BBSUS data were used to fit flight height distributions to most species. The Grey falcon is listed as Vulnerable. Simulation results for this case showed low-medium threat.

4 Methods

The Band model (Band *et al.* 2007) has long served as a standard framework for collision risk estimation (Cook *et al.* 2025), either directly or through derivative models. The Band model uses a vertical plane to estimate passage of a particular species along a single two-dimensional line across the wind farm. This neglects the three-dimensionality of the wind farm and therefore overestimates the likelihood of a bird passing through the RSA. Although there is a "large array" correction in the model it does not sufficiently compensate for the third dimension. However, the Band model has been benchmarked against post-construction collision datasets and is retained here as the benchmark method alongside the site-specific New Model.

To consider the particular situation at Bonney Downs Station and to implement a fully three-dimensional study to compare with the Band model, a New Model was developed that includes a fully three-dimensional simulation and provides estimates based on bird behaviour and spatial separation of the WTG. The New Model allows more site-specific information to be incorporated as more data is obtained.

In what follows there is a summary of the history of collision risk models, information on how the bird species were chosen for simulation, and how the data were prepared. We modelled collision likelihood using the Band model and also developed a novel CRM. Due diligence dictates that both models be used to consider the Bonney Downs Generation Hub and Nullagine Pilot Wind Farm, so summaries of both the Band model and the new model are given. Simulations were performed using both models and the results were compared to provide a final assessment.

4.1 Collision Risk Models

Cook *et al.* (2025) published a review of 52 CRM models that have been published over the last 40 years. These models include a total of 75 input parameters (**Table 3**), with increasing complexity over time, moving from collision with individual turbines, to impacts of whole wind farms. The total number of parameters used ranges from 4 to 22 (median 15) (Cook *et al.* 2025). Whilst the original CRM used only 5 input parameters (Manning 1983), an increasing number of parameters is typical of more recent CRM, with the widely used Band *et al.* (2007) model – the model that we have applied on first principle – requiring 20 parameters.

Next to specifications of the wind turbines (rotor diameter capturing the rotor swept area, maximum width of blade, rotation period, number of turbines, hub height, pitch, number of blades), aspects of bird behaviour around wind turbines (avoidance rate, body length, flight speed, wingspan, % time at Critical Risk Height) are central to CRMs (**Table 3**).

Table 3. *Parameters included in 52 Collision Risk Models (CRM) (calculated from data presented in Cook et al. 2025). Colours reflect parameters included in few to many (blue to red) models.*

		CRMs including this parameter	
Category of parameter	**Parameter**	**Count**	**%**
Bird behaviour and morphology	Avoidance Rate	36	69%
	Body length	34	65%
	Flight speed	32	62%
	Wingspan	30	58%
	% time at Critical Risk Height	28	54%
	Flap or glide	18	35%
	Continuous flight height distribution	10	19%
	Collision rate	8	15%
	Flight Direction	7	13%
	Number of Turbines encountered	6	12%
	Flight behaviour (e.g. Foraging, commuting etc)	5	10%
	Flight angle to headwind	3	6%
	Probability of safe passage	2	4%
	Point of Entry	1	2%
Parameters used to estimate bird flux	Bird Flight Activity	20	38%
	Population Size	16	31%
	Time Flying per Day	11	21%
	Nocturnal Activity	10	19%
	Bird Density	8	15%
	Distance to Nest	5	10%
	length of breeding season	5	10%
	% Time in Wind Farm	5	10%
	% time in different habitats	3	6%
	Distance to Conspecific Nest	2	4%
	Body Mass	2	4%
	Foraging range	2	4%
	Departure direction	1	2%
	Distance to coast	1	2%
	Distance to Fishing Harbour	1	2%
	Movement Probability	1	2%

Category of parameter	Parameter	CRMs including this parameter Count	%
	Basal Metabolic Rate	1	2%
	Foraging Efficiency	1	2%
	Energy Density of Prey	1	2%
Weather and landscape parameters	Wind Speed	12	23%
	Wind Direction	5	10%
	Terrain Altitude	5	10%
	Air Density	3	6%
	Land use and habitat	3	6%
	Terrain Slope	3	6%
	Water Depth	2	4%
	Human population density	2	4%
	Distance to Slope	2	4%
	Precipitation	1	2%
	Visibility	1	2%
	Temperature	1	2%
	Heat flux	1	2%
	Surface pressure	1	2%
	Humidity	1	2%
	Solar Radiation	1	2%
	Boundary Layer Height	1	2%
	Fishing vessel presence	1	2%
	Terrain Aspect	1	2%
Wind farm parameters	Number of Turbines	31	60%
	Operational time	23	44%
	Wind Farm Area	18	35%
	Turbine Locations	10	19%
	Distance between turbines	3	6%
	Number of Turbine Rows	2	4%
	Distance to Wind farm	1	2%
	Distance between Turbine rows	1	2%
Wind turbine parameters	Rotor diameter	39	75%
	Maximum width of blade	32	62%
	Rotation period	32	62%
	Hub height	29	56%
	Pitch	28	54%
	Number of Blades	27	52%
	Maximum rotor tip height	23	44%
	Minimum rotor tip height	20	38%
	K (1D or 3D)	18	35%
	Turbine surface area	8	15%
	Blade thickness	3	6%
	Cut in speeds	2	4%
	Nacelle Width	2	4%
	Power coefficient	1	2%
	Monopole diameter	1	2%

Of the 52 models reviewed by Cook *et al.* (2025), it was observed that only 23 out of 52 contained sufficient information to recreate the model; in some cases, this was because the model is regarded as proprietary software and commercially sensitive (e.g., Smales *et al.* 2013). This observation highlights the importance of CRM models that can be run in an efficient and transparent manner, with the process and results accessible to all stakeholders including regulators, developers and their consultants.

All these different models have a common methodology, and the differences are in the level of detail and sophistication. Each model includes evaluation of three components:

(1) what is the likelihood of a bird being in the danger region close to the turbine,

(2) what is the likelihood they will fly through the rotor sweep, and

(3) what are the chances of being hit if they do?

The earliest models (e.g., Band *et al.* 2007) used very simple probabilistic arguments, for example dividing the volume of the region very close to the turbine by the volume of the birds' expected daily travel and using that as a probability of being co-located with the turbine. This requires very little in the way of data, but only knowledge of the bird's daily habits. However, even this is sometimes difficult to obtain and may vary greatly between bird species.

Later models began to incorporate data on expected flight height for each species, and GPS data were used to map behaviour to present a clearer picture of activity. For example, Hull and Muir (2013) used extensive data on the movement of Tasmanian Wedge-tailed eagles (*Aquila audax*) and White-bellied sea eagles (*Haliaeetus leucogaster*) to determine their flight heights and locations, and were able to quantify turbine avoidance. The decision on whether a bird would be struck began with calculations of given bird size and speed compared to rotor speed and thereby computed likelihood of direct collision (Band 2007). This aspect has also been improved to include the direction of flight and wind speed calculations and how they modify the likelihood of collision (Holmstrom *et al.* 2011, Christie & Urquhart 2015).

If there is sufficient data about a particular species, the likelihood of being in the vicinity of the rotors can be estimated with more confidence. For example, Murgatroyd *et al.* (2021) analysed GPS data for the behaviour of Verreaux's eagle (*Aquila verreauxii*) and found their most favoured habitat was in countryside with slopes to assist in soaring. They were able to make more confident predictions of the best locations for the turbines to avoid encroaching on areas preferred by the eagles. Therefore, they were able to recommend safer places for the turbines and buffer zones to minimise bird-turbine interactions.

A more sophisticated model is possible if suitable data collected from an existing windfarm can be used to inform the model [e.g., Biosis modelling has been used in Wedge-tailed eagle and White-bellied sea-eagles (Smales *et al.* 2013) and Bayesian modelling in other raptor species (Adachi *et al.* 2015)], or where aerodynamic parameters can be derived through flight modelling.

However, these enhancements and improvements require a very large data collection exercise that is not always feasible. Throughout this historical evolution, because of its fundamental importance in the field and its simpler data requirements, the Band model has consistently remained central to many analyses. It has continually improved and kept up with the latest developments. In 2012, a stochastic component was introduced to each phase of the Band Model algorithm, so that both inputs and outputs include statistical variation. For example, mean flight height as a determinant of interaction with the rotor sweep was replaced by a distribution with mean and variance determined from field data. Several options for the shape of this distribution were employed in the Band model.

Due to its widespread use, the decision was made that the collision risk modelling should include the use of the Band (2012) model. However, after implementation we found that there were some limitations in the model in terms of predicting proximity of birds to turbines. As a result, a new model was developed to address this issue. The implementation of the Band model and the New Model are described below.

4.2 Choice of Species for modelling

Of 128 bird species recorded at Bonney Downs, 17 have been recorded flying at heights that would place them within the RSA; this total includes 8 raptor species (**Table 4**). This relatively low number is partly due to the very high RSA of the proposed turbines (>100m), with many species never recorded flying at or above that height. Another 3 raptor species were reported at the site (although none of the observations put them at RSA height) (**Table 4**). Modelling was carried out for 13 bird species using data from the eight Bonney Downs BBSUS conducted as part of this project (*ecologia* Environment 2025) and data from the two Robin Radar MAX placements. The choices made were dictated by the available data. CRM analysis was not carried out for some species where:

(1) There were insufficient flight height data records for robust analysis; for example, records of the Black falcon (n=1 sighting) and Black kite (n=5 sightings) were insufficient to generate accurate estimates of flight height. The low numbers of records during BBSUS (*ecologia* Environment 2025) suggests their presence at Bonney Downs Station is very low. In the case of Australian magpie and Yellow-throated miner, there was insufficient records of flight heights within the RSA for modelling.

(2) All of the data showed a species to be below the proposed RSA, including two migratory species: Oriental plover and Pacific swift. We note that 7 of these species recorded at Bonney Downs Station (Black-necked stork, Pacific swift, Australian hobby, Little eagle, Little woodswallow, Square-tailed kite, White-bellied sea-eagle) have been identified as having 'high' overall risk of wind turbines (assessment includes collision risk, habitat displacement, and population effects) according to the Reid analysis (Reid & Baker 2025, Reid *et al.* 2025), see **Table 4**. However, this assessment estimated threat of collision for an RSA between 30 to 275 m, and their assessment was largely based on expert elicitation. We have no records of these species flying at heights that would place them at risk of the proposed wind turbines (100–280 m RSA).

Thus, the final set of 13 bird species modelled was chosen based on the available BBSUS data.

Table 4. *Data for 33 bird species observed at Bonney Downs Station and some of their characteristics, and information on modelling status.*

	Species		Body mass average (g)[†]	Mortalities recorded across Australian wind farms [1]	Number of sightings	Proportion of flight records within RSA	Sufficient data to model collision risk †	Reid overall risk CATEGORY[‡]
Bird species recorded at RSA height								
1	Australasian darter	*Anhinga novaehollandiae*	1630		38	0.0526	Y	high
2	Australian kestrel	*Falco cenchroides*	180	54	439	0.0182	Y	high
3	Australian pelican	*Pelecanus conspicillatus*	5426		10	0.2	Y	high
4	Brown falcon	*Falco berigora*	587	48	177	0.079	Y	high
5	Grey falcon **(VU[1])**	*Falco hypoleucos*	471		33	0.303	Y	high
6	Little black	*Phalacrocorax sulcirostris*	967		72	0.347	Y	high
7	Masked	*Artamus personatus*	35	1*	17	0.411	Y	high
8	Spotted harrier	*Circus assimilis*	570	1	103	0.0582	Y	high
9	Straw-necked ibis	*Threskiornis spinicollis*	1353	1*	43	0.325	Y	high
10	Torresian crow	*Corvos orru*	555	41*	77	0.169	Y	medium
11	Wedge-tailed eagle	*Aquila audax*	3558	58	210	0.304	Y	high
12	Whistling kite	*Haliastur sphenurus*	745	5	151	0.0993	Y	high
13	White-necked heron	*Ardea pacifica*	893		25	0.12	Y	high
	Species with too few records for flight height (required for CRM analysis)							
14	Black falcon	*Falco subniger*	744	1	1	1	N_L	high
15	Black kite	*Milvus migrans*	825		5	0.2	N_L	high
16	Australian magpie	*Gymnorhina tibicen*	275	115	37	0.03†	N_L	medium

	Species		Body mass average (g)[†]	Mortalities recorded across Australian wind farms [1]	Number of sightings	Proportion of flight records within RSA	Sufficient data to model collision risk †	Reid overall risk CATEGORY‡
17	Yellow-throated	*Manorina flavigula*	57		453	<0.01	N-L	medium
Other species that have been identified at risk of turbine collision risk (either published mortalities or expert elicitation: Reid & Baker 2025, Reid et al. 2025), but were not recorded at RSA flight heights at Bonney Downs								
18	Australian bustard	*Ardeotis australis*	5238		23	0	N(RSA)	medium
19	Australian hobby	*Falco longipennis*	247	1	22	0	N(RSA)	high
20	Black-necked stork [2]	*Ephippiorhynchus*	4197		2	0	N(RSA)	high
21	Black-faced	*Coracina novaehollandiae*	115		38	0	N(RSA)	medium
22	Black-shouldered kite	*Elanus axillaris*	272		10	0	N(RSA)	medium
23	Budgerigar	*Melopsittacus undulatus*	28		1937	0	N(RSA)	medium
24	Horsfield's bush lark	*Mirafra javanica*	23		99	0	N(RSA)	medium
25	Little eagle	*Hieraaetus morphnoides*	812	1	1	0	N(RSA)	high
26	Little woodswallow	*Artamus minor*	17		4	0	N(RSA)	high
27	Magpie-lark	*Grallina cyanoleuca*	79	13	111	0	N(RSA)	low
28	Oriental plover **(MI)**	*Charadrius veredus*	95		1	0	N(RSA)	medium
29	Pacific swift **(MI)**	*Apus pacificus*	42		12	0	N(RSA)	high
30	Painted finch	*Emblema pictum*	11		466	0	N(RSA)	low
31	Rainbow bee-eater	*Merops ornatus*	29		106	0	N(RSA)	medium
32	Square-tailed kite	*Lophoictinia isura*	647		1	0	N(RSA)	high
33	White-bellied sea-	*Haliaeetus leucogaster*	2900		1	0	N(RSA)	high

† Data for collision risk modelling *Y: yes sufficient data to model collision; N(RSA) no records of flights within the RSA; N: insufficient flight height data, no CRM carried out; N-L: insufficient numbers of flight height data within the RSA to carry out CRM.*

‡ Reid used an RSA of 30 to 275 m for their evaluations.

Conservation listings *Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC) Act (**VU** Vulnerable, **MI** Migratory species protected under international agreement).* [1] This species is specially protected under international, Federal and State legislation – the species is listed as Vulnerable under the IUCN Red List, 'Vulnerable' under the Commonwealth EPBC Act, and Criterion 4 ('Vulnerable') under the Western Australian Biodiversity Conservation Act 2016. [2] Globally listed as Near Threatened (NT) by the IUCN Red List.

It is possible to use the simulation model to consider bat collision, but at the time of writing there was insufficient data to perform this. An analysis of the threat to bats based on habitat and behaviour is considered in *Project 2.1.3 Literature review and bat traits analysis* (Fleming & Dempster 2026), providing an indication of which species may be under threat of collision.

4.3 Data Sources and Preparation

The input data required for the models includes bird physical characteristics (body length, wingspan, etc.), bird behaviour (flight height distribution, flight speed, active time, etc., see **Table 5**) as well as the turbine characteristics (hub height, blade length, rotor size, pitch and speed) and operational details of the wind farm (number of turbines, size of the farm and operational strategy – see **Tables A9** and **A10**). The most difficult to obtain are bird flight characteristics, particularly flight height distribution, i.e. time spent at rotor swept height and time in the air.

Table 5. *Input data for the models.*

	Body Length (m)		Wingspan (m)		Flight Speed (m/s)		Proportion in RSA	
Species	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Australasian darter	0.900	0.020	1.220	0.003	15.252	3.870	0.062	0
Australian kestrel	0.320	0.020	0.720	0.030	9.358	2.530	0.047	0.026
Australian pelican	1.700	0.0625	2.450	0.075	15.221	2.106	0.183	0
Brown falcon	0.445	0.008	1.015	0.068	11.770	3.396	0.090	0.043
Grey falcon **(VU)**	0.365	0.033	0.915	0.033	11.787	3.360	0.132	0.034
Little black cormorant	0.600	0.0275	1.000	0.025	13.894	4.179	0.1171	0
Masked woodswallow	0.190	0.00625	0.330	0.005	9.290	4.039	0.151	0
Spotted harrier	0.555	0.028	1.340	0.065	8.337	2.459	0.050	0.041
Straw-necked ibis	0.650	0.050	1.100	0.050	14.631	3.912	0.183	0
Torresian crow	0.490	0.0175	1.000	0.1675	11.348	3.708	0.002	0
Wedge-tailed eagle	0.955	0.053	2.013	0.086	15.409	4.922	0.266	0.092
Whistling kite	0.550	0.020	1.330	0.065	10.799	3.203	0.137	0.050
White-necked heron	0.910	0.075	1.550	0.06	10.196	3.110	0.072	0

Bird dimensions are taken from the Australian Database of birds, and the flight speed from modelling (Klein Heerenbrink 2023). The proportion of time at risk height is computed from the BBSUS observations.
Conservation status *(DBCA 2025):* ***VU*** *Vulnerable (IUCN, EPBC Act, WA BC Act).*

Having detailed flight height data allows us to fit statistical distributions to identify the best fit for flight height. The preparation of the flight height data can be summarised in two examples. The Grey falcon had far fewer recorded sightings than the Wedge-tailed eagle. Using the estimated heights of the records for the Grey falcon (**Figure 1**), simulations provide log-normal flight height distribution (green line in **Figure 1**). For the Wedge-tailed eagle, the log-normal distribution also provided an excellent fit (**Figure 2a**) and was more reliable because of the availability of more data. Knowledge of the underlying distribution is valuable because it enables estimation of the likelihood of birds being at risk of collision using only the distribution parameters (mean and standard deviation).

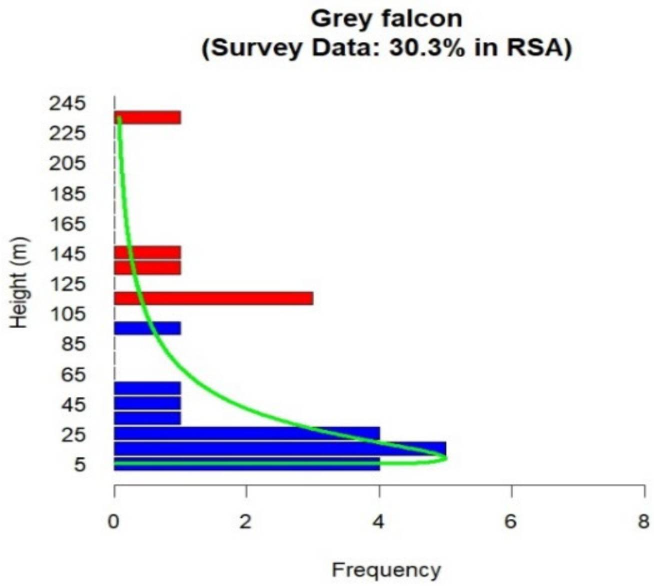

Figure 1. *Histogram of flight height data for the Grey falcon taken from BBSUS data, along with the corresponding fitted log-normal distribution used for the simulation model flight heights.*
Blue bars represent flight heights below, and red bars flight heights that would fall within the rotor swept area (RSA) (i.e., 'at risk' of turbine collision).

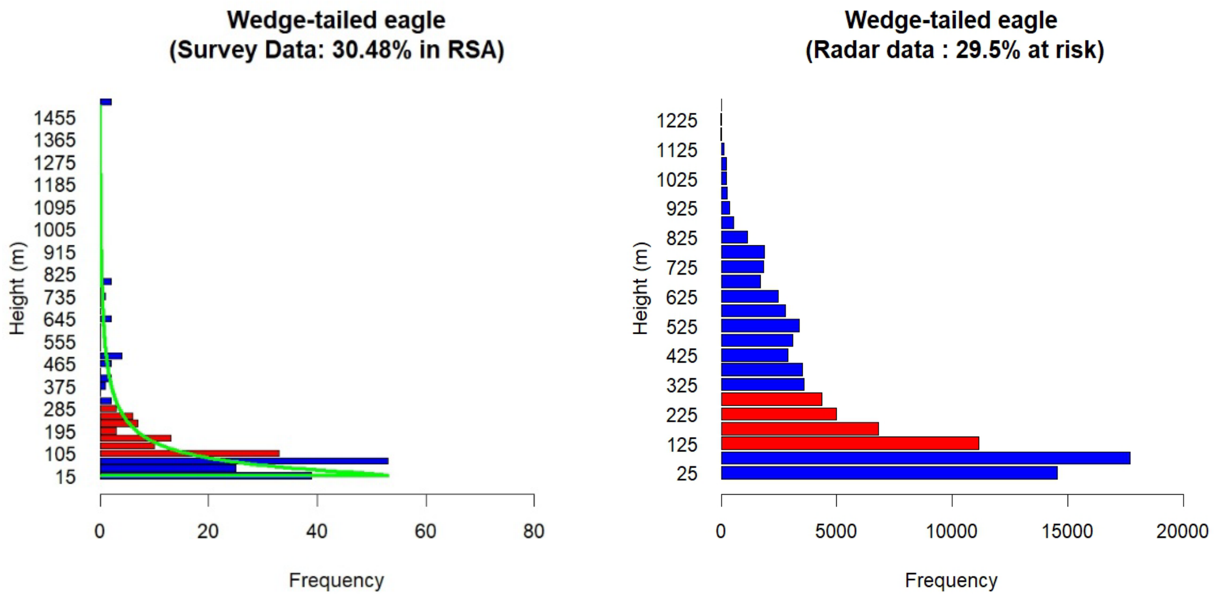

Figure 2. *Histograms of data from BBSUS (left) and radar data (right) for the Wedge-tailed eagle.*
These data were used to fit distributions that reflect flight heights. Blue bars represent flight heights below or above, and red bars flight heights that would fall within the rotor swept area (RSA). Indication is for time at RSA (i.e., 'at risk' of turbine collision).

A similar process to obtain time in the rotor swept area (RSA) of the proposed wind turbines (100–280 m) was used for all other species for which there was sufficient data (see **Table 5**). For each species, histograms of the flight heights from all recorded sightings across eight Bonney Downs BBSUS (*ecologia* Environment 2025) were plotted to estimate the likelihood of birds flying within the proposed turbine RSA. Statistical summaries of the parameters of flight height distributions were then used to generate a distribution of flight heights using multiple simulations.

As a comparison and test of the approach, radar data collected over one week, including various bird classes was analysed. We focused on daytime records for the 'medium bird' radar category, which includes species such as the Wedge-tailed eagle (visual observations match this radar category with Wedge-tailed eagles for the majority, >95%, of instances). For birds in this category, it was possible to extract key flight parameters, namely, elevation and airspeed, to characterise their flight height distribution. These data were collated and fitted with a log-normal distribution (**Figure 2b**) for comparison with direct visual observations from the Bonney Downs BBSUS data. The radar data indicates that approximately 29.5% of the flying time for the birds in this category (most likely Wedge-tailed eagles) lies within RSA, a result that is close to the survey-based estimate (which was 30.48%) but is more accurate due to the higher temporal resolution of the radar observations. This serves as a verification of the fitting of flight heights to the available BBSUS data. Radar data for other species are not available as this requires substantial field validation through direct observation.

4.4 The Band Model

The Band model was originally developed to calculate the collision rate for greylag geese (*Anser anser*) and hen harriers (*Circus cyaneus*) at an individual wind farm near Dounreay, Scotland. The 2012 model (Band 2012) was an update of the model to facilitate application in the offshore environment, given that direct observations of birds from key vantage points – in respect to gathering information on flight activity – are not usually possible in the marine environment. As it is noted that the flight height distribution for many species is not uniformly distributed (e.g., Schaub *et al.* 2023, Schaub *et al.* 2024b), the model was extended to make use of data on the distribution of bird flight heights (Band 2012). The model includes stochastic variation in all parameters, and a multi-simulation approach is used. The code is written in the statistical package 'R' and comes with a set of default parameters that can be used in the absence of data for a particular site.

Monthly wind speed averages are used in the Band model to estimate WTG rotor speeds, and these have a distribution, making the simulation more like the reality of wind variability throughout time. Inputs are mean and variance for each factor. Multiple simulations (often thousands) representing data over a year are conducted using different distributed input parameters. Thus, the output is not a single number for each bird species, but a distribution of probability of collision. In this report, only the mean percentage chance of collision in the Bonney Downs Station per year is reported.

For any collision risk model, there are three essential components: (1) the likelihood of a bird being near a wind turbine, (2) the chance the bird will fly within the RSA, and (3) the likelihood of a direct collision if the bird does fly through the RSA. The second and third components involve calculations that involve the bird's behaviour, flight height distribution and speed and how these are related to the speed and size of the rotors and pitch of the blades. It is the first two components that require the most intense data collection. The Band model uses an extended two-dimensional plane for the first component, resulting in a higher number of interactions with the WTG than a fully three-dimensional simulation.

To be generally applicable, the Band model makes assumptions of uniformity across the wind farm. For example, the turbines are assumed to be evenly distributed across the area of the farm, birds of all species are assumed to be evenly spread, and most meteorological inputs are taken as monthly averages. Bird flights are assumed to fly across the line of the turbines and include upwind and downwind calculations.

The likelihood of being in the vicinity of the rotors is estimated using a line-of-sight survey to determine birds flying across this line during the survey. Once this is determined, the calculation of likelihood of actual collision is computed using flight speed and direction, rotor speed, time the rotor is in operation (given various power generation strategies and wind speed), and time for passage through the RSA.

Avoidance is a crucial factor in determining the final turbine collision rate but is an unknown quantity for most birds. The Band model has been "calibrated" over many years to improve consistency of results with field studies (fatality records). This calibration was obtained by comparing carcass numbers after the installation of the wind farm with predictions of the model (Urquhart & Whitfield 2016, Smales 2023), not with direct measurement or observation of birds avoiding the WTG (Hull & Muir 2013). The Band model is therefore routinely applied using high avoidance rates (99.5%). A 'worst-case' scenario for the Band model option 2 was carried out with 98% avoidance. Section 4.6 discusses this choice of avoidance rate in more detail.

There are three options for flight height distribution in the Band model (Band 2012, Masden *et al.* 2021):

- **Option 1:** This option uses a distribution about the mean flight height for each bird species to compute time at the danger level between the top and bottom of the RSA. The risk of collision is termed the Basic model, and no differentiation is made between the different heights within the RSA. Option 1 does not include wind direction, and a simple, direct avoidance is included. It produces much higher estimates of collision numbers because of the uniform flight height distribution.

- **Option 2:** The computation of flight height is based on detailed data collection for many species, that has been used to generate a generic shape function for flight height using a bootstrapping technique (Johnston *et al.* 2014). This distribution is then fitted for each bird using estimates of their flight height mean and variance. The direct collision risk is then integrated over the range in height of the rotor swept (e.g. near the base of the RSA is much less than at the height of the hub due to the greater width). Wind direction is not included. Avoidance is included as a percentage.

- **Option 3:** This option is very similar to Option 2, including the same factors, but with a more sophisticated calculation of the passage through the RSA, including wind direction and more detail of the rotor geometry and flight direction. The flight height data in options 2 and 3 can be modified for a particular species Simulations revealed that the results of Option 3 were very similar to Option 2 for all species modelled, so only the results of Option 2 are quoted in this report.

For each option, the output of the Band model is a monthly display of a distribution of collision likelihood as well as a total risk. Variation in the monthly output is due to changes in wind strength and bird density (both inputs are averaged for each month). In this report we have included only mean collision percentages, rather than the full plots.

Calculations of likelihood of passing through the RSA are based on a two-dimensional, vertical plane through which all birds must pass. The area of RSA of all turbines is then divided by the total area of this plane, providing an estimate of the number of passages. It was determined that the Band model over-estimates the number of passages through the turbines. This calculation is not appropriate for farms with a very large number of turbines.

4.5 The New Model

Limitations of the Band model are in the computation of the number of interactions that a particular bird species has with the WTG. The method overestimates the number of interactions because it assumes an extended two-dimensional plane in which the WTG are situated. This approximation therefore omits the third horizontal dimension. This approximation is reasonable for small numbers of turbines but breaks down when there are large numbers of WTG, as in the proposed wind farm at Bonney Downs. Historical records and calibration of the Band model (Urquhart & Whitfield 2016, Smales 2023) allow it to produce good estimates when compared to collision data. However, in order to compare with a more three-dimensional approach, a new model was developed with an improvement in this aspect of the methodology. Simulations were performed with a full three-dimensional model of the region, thus giving a more accurate representation of the density of bird flights in the vicinity of the WTG.

The new collision likelihood model is, like all others, based on three key components: (1) the use of flight height distributions consistent with those required in the Band model, (2) a calculation of strike frequency during passage, comparable to the Band model but slightly simplified, and (3) the simulation of bird movement across the region according to species-specific speeds and travel distances. Together, these components provide a framework analogous to that of the Band model but item (3) provides a full three-dimensional representation of the wind farm.

Statistical simulations were used to represent random movement of birds across both wind farms at Bonney Downs Station. Turbines were positioned approximately in their planned locations, and bird flights of varying lengths were generated according to species-specific flight speeds and travel distances, uniformly distributed across a reconstructed map of the Bonney Downs Station including approximate WTG locations (see **Figure 3**). Simulations with the New Model included 15,000 random flights of length ranging from 10 to 40 km, estimated from flight speeds and time in the air. These were randomly simulated across the Bonney Downs Station and a small buffer area around it to take account of nearby bird populations. The starting points and travel directions of the flights were chosen randomly from a uniform distribution. The proportion of these 'flights' that crossed the 200 m-long lines representing the WTG were then counted, allowing determination of the number of times there would be an intersection of the bird with a WTG per distance travelled. Thus, for each species, the speed and flight characteristics were used to compute the likelihood of an interaction with the WTG.

Extensive trial simulations show that if the motion is completely random (i.e., **Figure 3**), then the likelihood of being in any location is equal to any other. Therefore, the likelihood of a collision depends mainly on distance travelled, and only slightly on the length of each individual flight. As a result, one of the most important factors for each bird species is the distance an individual bird would need to travel before it would be struck. For example, given certain parameters, a Wedge-tailed eagle might travel close to 10,000 km before being struck. While this sounds like a long distance, it is less than the approximate distance an eagle travels in a year (Cherriman 2024), which may be up to 25,000-30,000 km.

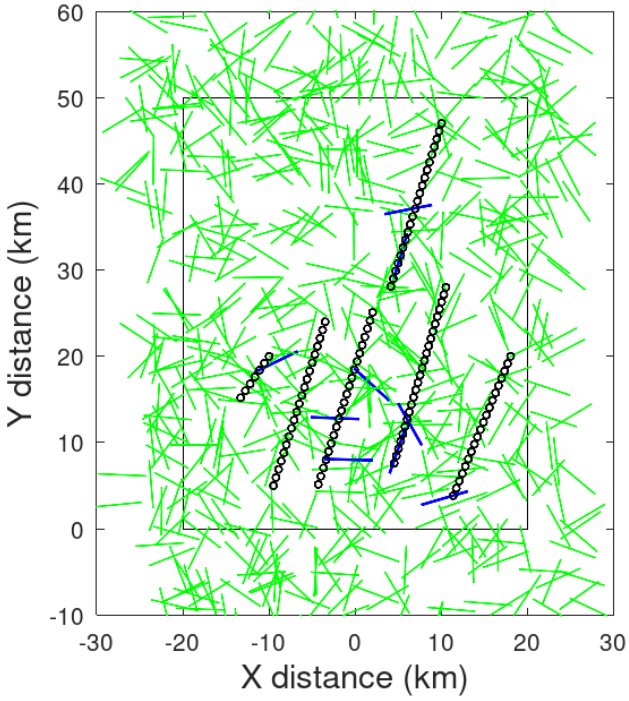

Figure 3. *Simulated random bird flight paths.*
The small circles indicate turbine locations and the green, lines are simulated bird flights. The blue lines close to the turbines are cases in which the flight crosses the location of a turbine. Not every flight that crosses the line of WTG will involve a potential collision as they may pass between them. This example has a uniform distribution of flights and shows only 500 “flights”. Simulations for each bird species involved 15,000 flights.

4.6 Choice of Avoidance Rates

Collision risk models first estimate potential collisions assuming no avoiding action, then apply an avoidance rate to account for behavioural responses that reduce exposure and collision probability. Accordingly, the avoidance rate used for modelling should be interpreted as an overall, pragmatic correction factor capturing multiple processes (e.g., displacement and evasive behaviour) that are not explicitly represented in the geometric collision calculation, rather than a single observed avoidance mechanism at one spatial scale. NatureScot’s updated onshore CRM guidance explicitly states that avoidance rates used in collision risk estimates should be characteristic of overall avoidance (including both behavioural displacement and behavioural avoidance) and recommends presenting outcomes across a high avoidance range (e.g., 98%, 99% and 99.5%) where species-specific information is limited (NatureScot 2025). On this basis, the Band Model is retained as the benchmark, with 99.5% as the base case and 98% as a conservative “worst case” that remains within plausible overall avoidance values, while still providing a strong stress test (a four-fold increase in the non-avoidance multiplier relative to 99.5%). This is consistent with guidance that many species exhibit avoidance ⩾98% and that 98% is an appropriate default where species-specific evidence is unavailable (NatureScot 2025), and with Australian synthesis for species such as Wedge-tailed eagles indicating avoidance is likely to be very high (Biosis 2006).

The New Model adopts 90% as the conservative comparability scenario for calibration/sensitivity testing. However, avoidance inputs must remain within scientifically plausible ranges because they function as correction factors during model calibration. Extremely low overall avoidance values should not be treated as candidate inputs without strong, site-specific empirical evidence demonstrating such low overall avoidance is realistic (Smales 2023).

5 Results

5.1 How to interpret this report

- This report provides an assessment of the likelihood of birds of different species colliding with the WTG at the proposed BDGH and the Nullagine Pilot Wind Farm (currently under development). The assessment is based on BBSUS data collected on site and on simulations using two models: the Band model commonly used in international studies and a new model developed for this project.

- Results are presented as an estimate of *the percentage of the local population that may be struck by the turbine blades over a one-year period* within two wind farms at Bonney Downs Station and a surrounding 5 km zone. For example, a value of '10%' indicates that an estimated 10% of the local population may collide with the blades in one year. In other words, if there are 100 birds in the region, then the modelling suggests 10 may be struck during the year. It is unlikely that most bird species would survive direct impact, and so these numbers represent predicted fatalities. Since the calculation is a percentage, it automatically adjusts as the population changes (so in the next year, assuming no replacement, 9 bird collisions are predicted).

- For birds in very low numbers, such as the Grey falcon, this percentage can be read as the likelihood of collision within the year. For example, if there are 4 individuals and the predicted collision risk is 1.86% (Band Option 2 model), it suggests that, on average, you might expect 1 bird to be struck every 12 years. Under the New Model with 90% avoidance (1.6% collision risk), you might expect 1 bird to be struck every 14 years.

- Birds that are not considered herein were deemed to be at low chance of collision because they were never observed at the height of the rotor swept area (RSA), or there were insufficient data to predict their probability of collision.

5.2 Results of simulations

Simulations were performed for 13 bird species identified in the BBSUS surveys as described in **Table 4**. Comparison of the model outcomes for the 13 bird species are shown in **Table 1**.

It should be noted that the collision risk estimates presented below represent inherent (unmitigated) collision risk and do not account for the potential reduction achievable through management and design measures that may be adopted during project development or operations (e.g., curtailment, deterrent/monitoring systems, or blade marking/painting).

Results of the Band model using Option 2 (avoidance rate of 99.5%) for each species are indicated. The Band model results are quite sensitive to avoidance rates. A worst-case is simulated with 98% avoidance. A high-avoidance sensitivity set is commonly presented where species-specific avoidance data are limited. As the Band avoidance factor is applied as a single multiplier to the pre-avoidance collision estimate, the 98% case primarily scales predicted mortality magnitudes rather than changing the relative risk ranking between species; therefore, species-by-species discussion focuses on the base case, with 98% retained as a bounding sensitivity (Smales 2023; NatureScot 2024).

The New Model had a more consistent methodology for computation of time interaction with the WTG. For these calculations, 90% avoidance is used as a conservative sensitivity value to support comparability with Band outputs; it should not be interpreted as a definitive species-specific overall avoidance rate for the wind farms at Bonney Downs Station. Using the 90% avoidance factor, these collision likelihood values were such that only the Australian pelican (5.25%), Straw-necked ibis (2.75%) and Wedge-tailed eagle (4.47%) were found to be above 2% mortality per annum (**Table 1**).

A summary of the results for the **Band Option 2 model (99.5% avoidance)** and the **New Model with 90% avoidance** are discussed separately for the 13 species modelled.

Australasian darter – CRM models produced estimates of less than 3% mortality of the local population per year (1.98%, 1.12%). While the Australasian darter was only recorded in the RSA on 6% of occasions and is predicted to fly quickly (so would pass through the rotor zone in a relatively shorter time, reducing the chance of collision), this is a relatively large bird, with an average body length of around 90 cm, which would increase its collision risk. We note that this is likely a conservative estimate for Australasian darter which would likely spend only a small proportion of their time in flight (as they forage around water), as 29% of flight height records included instances where the birds were flushed when disturbed; their amount of flight time would therefore be less without such disturbance.

Australian kestrel – Collision likelihood is rated at less than 1% of population per year at Bonney Downs Station. This is a small bird species at around 30 cm body length, recorded spending less than 5% of its time at RSA. Although the result was a low risk of collision (0.44%, 0.57%), the kestrel was the most commonly recorded of the 13 species modelled (**Table 6**). Because they are a common species, Australian kestrel mortalities are frequently recorded at operational wind farms across Australia (**Table 4**), leaving little dispute regarding vulnerability to wind turbines for this species.

Australian pelican – This large bird averages 1.7 m in body length, flies at the RSA for around 18% of the time, and consequently has relatively high risk of turbine collision, the second highest of the species modelled. The Band Option 2 model produced lower percentage chance of collision (2.77%) than the New Model, which was about double this value (5.25%). This is an unusually large difference between the two models and depends on the slightly different computation of the passage through the WTG given the flight height distribution. The Band model has a more subtle approach to the passage calculation depending on the elevation within the RSA, so if the flight height distribution is weighted at the lower heights of the RSA, there is a lower risk of collision due to the narrowing of the blades.

Brown falcon – CRM models predict similar risk of 1.44% to 1.52% collision. These falcons are a small-medium bird of length around 50 cm. They have extremely rapid flight and regularly hover, but spend an estimated 9% of flight time at RSA, putting them at risk. Because they are a common species, Brown falcon mortalities are frequently recorded at operational wind farms across Australia (**Table 4**), leaving little dispute regarding vulnerability to wind turbines for this species.

Grey falcon (VU) – Listed as Vulnerable (EPBC Act), the Grey falcon is known to exist in small numbers at Bonney Downs Station. From the distribution of observations (**Figure 4**) and records of flight and nesting behaviour, there is likely one or two pairs of these birds present[1]. The Grey falcon is slightly smaller in size but has similar flight characteristics to the Brown falcon. However, direct visual observations identified Grey falcons flying at RSA height (13% of records at RSA heights) more often than Brown falcons (9% RSA), reflected in higher estimates of collision risk for Grey falcon (1.86%, 1.61%). This species has not been reported as a mortality at Australian wind farms to date, which could reflect non-overlapping geographic range with current operational wind farms, or strong avoidance behaviour.

[1] *observers positioned ~8 km apart reporting the same individual bird – identified from a missing tail rectrice – flying between hunting grounds and nest site.*

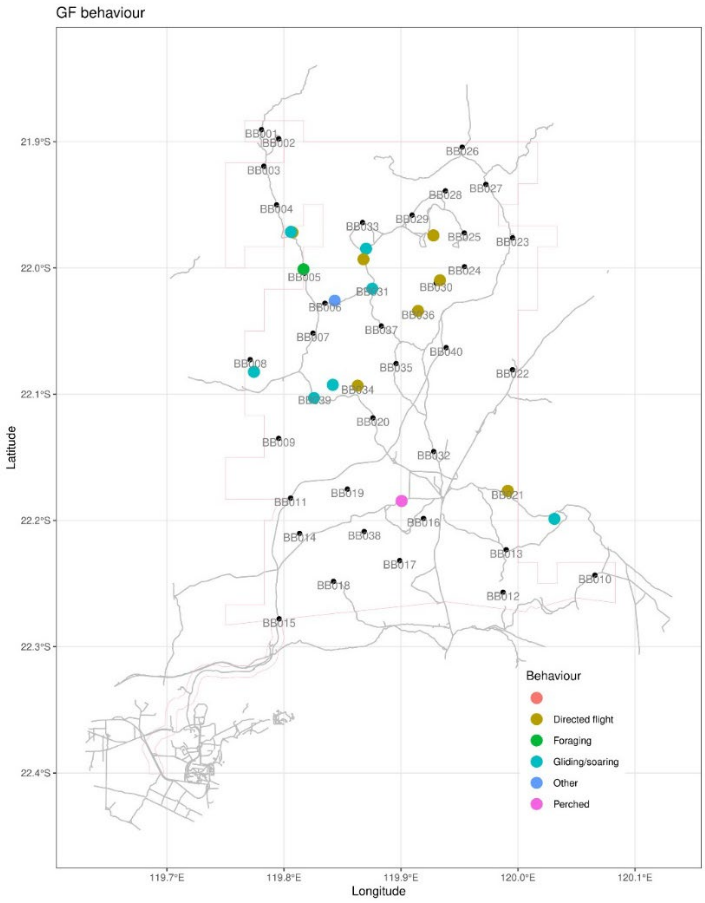

Figure 4. *Sightings of the Grey falcon (coloured dots representing different behaviour records) across Bonney Downs Station.*

Little black cormorant – This bird species was observed at RSA flight height on ~12% of occasions. It is a bird with body length ~60 cm and flies relatively swiftly. The larger time at RSA led to collision risk estimates of 2.04% and 1.35%. We note that this is likely a conservative estimate for Little black cormorant which would likely spend only a small proportion of their time in flight (as they forage around water), and 41% of flight height records included instances where the birds were flushed when disturbed; their amount of flight time would therefore be less without such disturbance.

Masked woodswallow – Spending around 15% of its time in the RSA places this bird species at high risk of collision. It is a smaller bird (at 20 cm) but flies more slowly than some of the others in this list. It spends the majority of its time foraging in flight. This combination of factors led to a probability of collision of 2.19% or 1.55%.

Spotted harrier – At around 50 cm in length, spending a large portion of each day quartering (foraging flight), and flying relatively slowly, Spotted harriers would be at high risk of turbine collision. However, these birds usually fly close to the ground – records identified these birds as spending only ~5% of time at RSA. These raptors were therefore modelled as having much lower probability of collision than the other raptors considered in this work (0.73%, 1.25%).

Straw-necked ibis – A medium-large bird (body length ~65 cm) that flies relatively quickly, these birds were commonly recorded at RSA heights (18% of records), placing them at risk of collision. This is reflected in the simulated percentage collisions per year, which was the third highest of the species modelled at 7.0% and 2.75%. We note that this is likely a conservative estimate for Straw-necked ibis which would likely spend only a small proportion of their time in flight (as they forage around water), and 18% of flight height records included instances where the birds were flushed when disturbed; their amount of flight time would therefore be less without such disturbance. For this species, the Band Option 2 model produced a value that was double that of the estimate derived from the New Model. This ibis has a lower collision probability than the Australian Pelican, which has been recorded with similar times at the RSA, because it flies at a similar speed but is much shorter, thereby spending less time in passing through the rotor blades.

Torresian crow – Very low risk of collision given its time in the RSA was observed at less than 1% of the time. As a result, the mean percentage of collisions was rated as less than 1% (<0.01%, 0.03%). Corvids have been commonly reported as collision mortalities at operational wind farms across Australia, which likely reflects small ground clearance for many currently operational wind farms (**Table 4**). The low collision predictions in the present study likely reflect the greater ground clearance to the proposed wind turbines (RSA 100–280 m) compared with current operational wind turbines (RSA from 30 m).

Wedge-tailed eagle – Collision predictions for the Wedge-tailed eagle are the highest of the 13 species modelled (11.67%, 4.5%). Hull and Muir (2013) give avoidance rates, from direct observation, 81-97% for Wedge-tailed eagles in Tasmania. In the Band model, recalibration of the data (see Section 4.4; Smales 2023) gives the equivalent range to be 96-99%. Despite high avoidance rates, this medium-large bird (body length ~1 m) spends around 30% of its flight time in the RSA and spends a large proportion of the day in flight. There are 27 territories mapped at Bonney Downs Station (**Figure 5**). If each territory is occupied by 2 adults (with an average of one fledged young), then the population size for the site is about 54 to 81 individuals. At 11.67% risk (Band Option 2 model), this equates to 6 adults plus 3 fledglings at risk per annum. At 4.47% risk (New Model with 90% avoidance), this equates to 3 adults plus 2 fledglings at risk per annum. Wedge-tailed eagle mortalities are commonly recorded at operational wind farms across Australia (**Table 4**), leaving little dispute regarding vulnerability to wind turbines for this species.

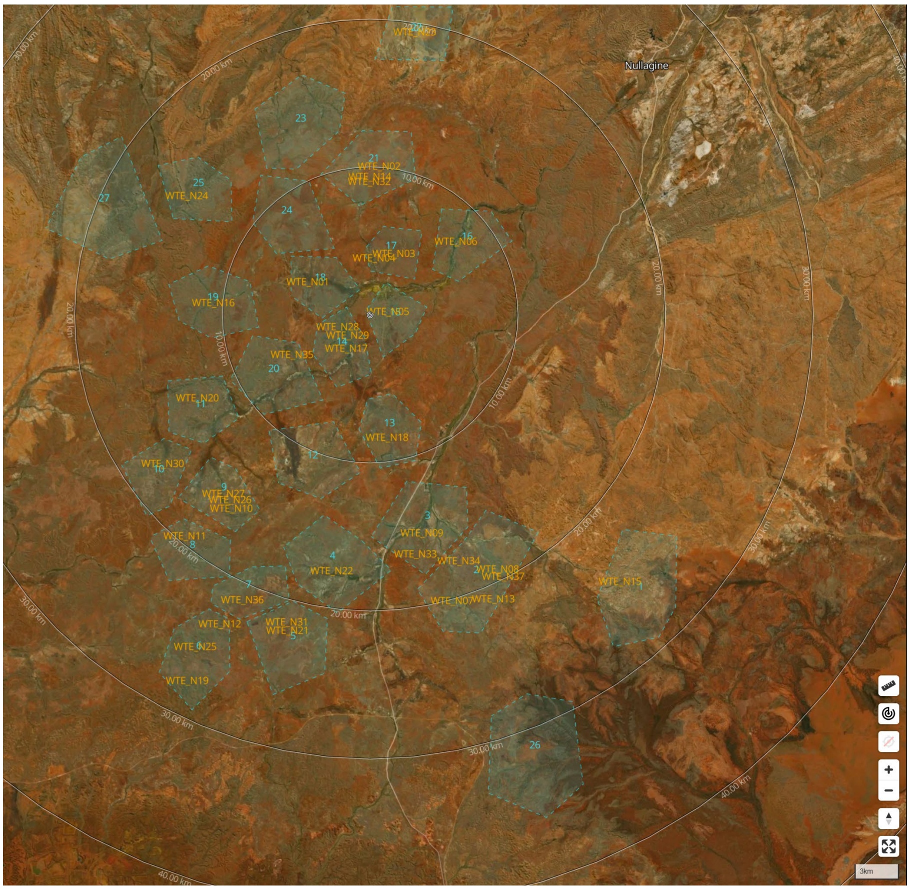

Figure 5. *27 Wedge-tailed eagle territories mapped across Bonney Downs (Ecologia).*

Whistling kite – This medium-sized raptor (body length ~50 cm) was commonly observed flying at RSA height (14% of records) and spends a large proportion of the day in flight. Consequently, this species has a predicted probability of collision of 1.75% or 1.98%. Whistling kites have been recorded as mortalities at Australian operational wind farms, although not commonly (**Table 4**).

White-necked heron – A relatively large bird (body length ~90 cm) that flies slowly compared to the others modelled in this study, but was observed at RSA less than 7% of the time. Predicted collision percentages were 0.55% and 1.20%. We note that this is likely a conservative estimate for White-necked heron which would likely spend only a small proportion of their time in flight (as they forage around water), as 21% of BBSUS flight height records included instances where the birds were flushed when disturbed; their amount of flight time would therefore be less without such disturbance.

5.3 Comparison of the Band model with the New Model

The Band model with Option 2 and the New Model used similar flight height distributions and bird characteristics, along with likelihood of collision during the passage of the bird through the RSA. However, the method of computing the number of transects through the RSA were differed between the two models. The models correlated strongly, as can be seen in **Figure 6**, which compares the Band model Option 2 with 99.5% avoidance against the New Model with 90% avoidance. **Figure 7** shows the correlation between the Band model with option 2 and the New Model with 90% avoidance. The New model generally estimates a lower number of collisions (despite including a lower turbine avoidance coefficient than required for the Band model) but the correlation is good.

Table 6 provides a detailed comparison of the different aspects of the Band model, used extensively in Wind Farm assessment, and the New Model which uses a different methodology to determine WTG proximity.

Collision risk for Bonney Downs has been assessed using both the widely accepted Band model and a project-specific three-dimensional collision risk model. The new model uses the same underlying collision calculation as the Band model but incorporates explicit turbine locations and simulated bird movement as well as a 3-dimensional representation of the wind farm. Under equivalent conservative assumptions, both models identify the same species as being of relatively higher likelihood of collision, and the New Model produces collision estimates that are similar to the Band Option 2 model.

In summary, the new 3-D collision risk model is at least as robust as the standard Band model, reproduces Band's species risk patterns under equivalent conservative assumptions, but provides a more realistic representation of the Bonney Downs wind farm. Comparison of the two models provides confidence in the integrity of both models and the reliability of the outcomes given the available input information.

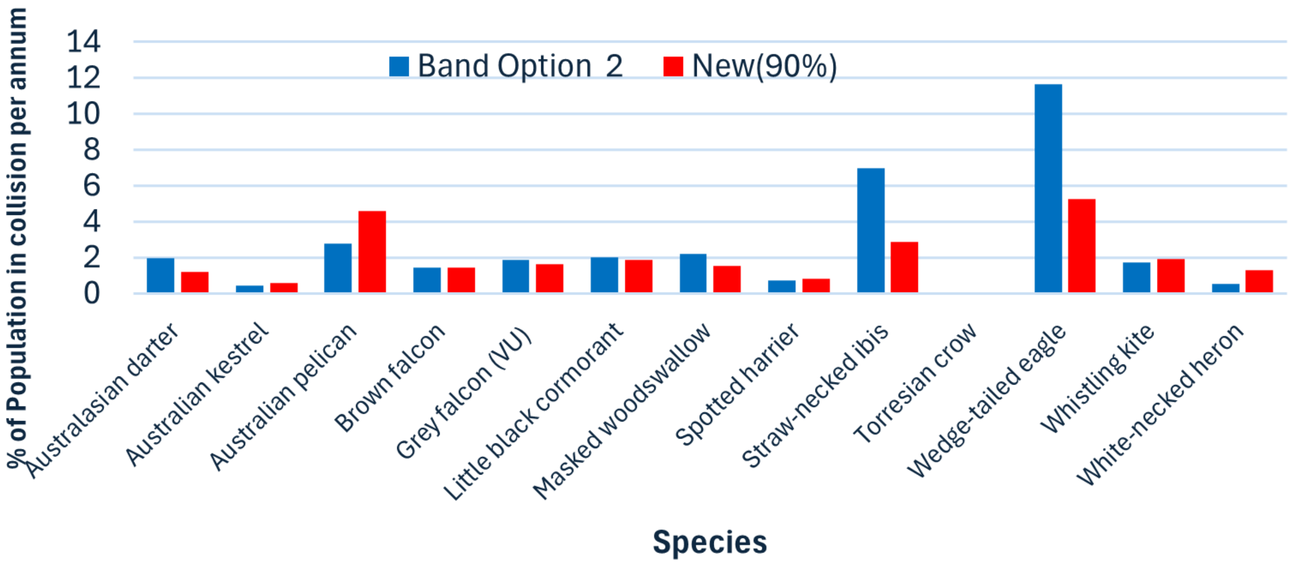

Figure 6. *Turbine collision predictions for 13 birds (expressed as a percentage of the population present at the site in a single year), showing Band model Option 2 (with 99.5% avoidance) and the New Model (with 90% avoidance).*

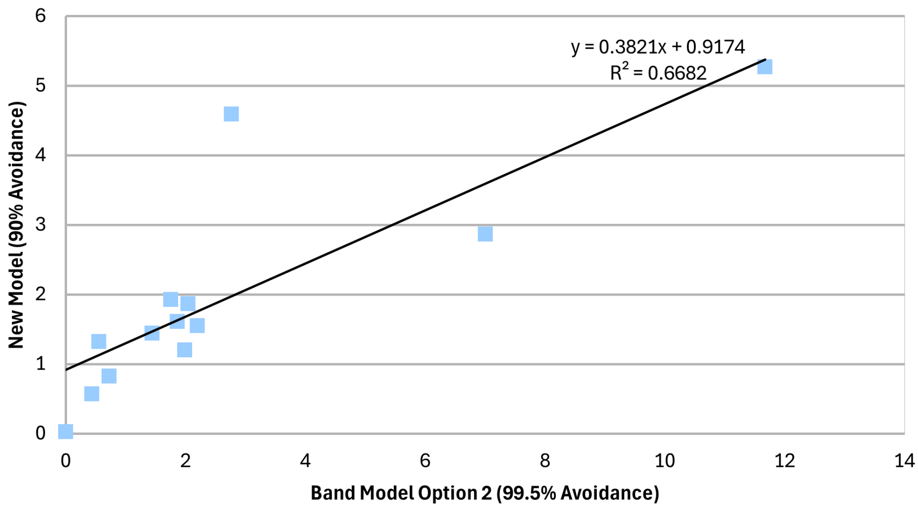

Figure 7. *Comparison of Band model Option 2 (99.5% avoidance) with the New Model (90% avoidance). The correlation is strong (R^2=0.67). There is greater variation for large birds with higher collision percentages.*

Table 6. *Comparison of the Band model and the New Model.*

Aspect	Band model	New 3-D collision risk model (Bonney Downs)	Assessment (New vs Band)
Role & purpose in this assessment	Provides a transparent, conservative estimate of bird–turbine collision risk and acts as the benchmark method.	Uses the same collision geometry as Band but in a 3-D, simulation tailored to the Bonney Downs layout; run in parallel with Band.	At least as good – provides context for Bonney Downs rather than a generic site. Keeps Band as the benchmark.
Regulatory status	Widely used and accepted in wind farm assessments; *strong regulatory precedent*.	New, project-specific tool presented in addition to Band, designed to be fully compatible with Band.	Band leads on precedent, but the New Model is clearly framed as an extension rather than a replacement. Includes more site specific details.
Core collision geometry	Analytical calculation of collision probability for a bird crossing the rotor disc using turbine and bird dimensions and speeds.	Uses the same geometric logic to calculate collision probability whenever a simulated bird overlaps a moving rotor.	At least as good – same physics and transparency, implemented in a more flexible engine.
Bird movement & layout representation	Birds represented as straight-line crossings of a 2-D rotor disc; turbine layout and topography are highly simplified.	Simulates individual 3-D bird trajectories through the actual turbine array, allowing repeated passes and complex paths, and can incorporate topography/habitat as data allow (this feature was not implemented in the present report due to a lack of data).	Better – more realistic spatial and movement representation, especially for a large, complex wind farm.
Treatment of time & operations	Typically assumes constant turbine operation and steady bird activity over time.	Very similar operation but capable of more time dependent analysis if data allows.	At least as good – capable of extension with better data input.
Inputs on bird use of airspace	Uses observed flight activity (e.g. flights/hour at rotor height) extrapolated across turbines.	Uses estimates of time that birds spend in the rotor-swept volume across the array, informed by site data and refinable with radar/other sources.	Comparable in data uncertainty, but better structured around time in the risky airspace.
Avoidance behaviour	Applies a single avoidance rate (e.g. 95–99%) as a scalar; results are highly sensitive to this assumption. *This value is a calibration of the model rather than a field measurement*.	Gives equivalent results to Band with lower numerical values of avoidance such as those measured in Hull and Muir (2013).	Currently “as good as” (same dependence on assumed rates) with clear potential to become better if real avoidance can be quantified in the field. Band avoidance is calibrated using post installation wind farm mortality (Urquhart and Whitfield, 2016, Smales, 2023)
Uncertainty & transparency	Uncertainty explored via scenarios (activity, avoidance); model structure is simple and well understood by regulators.	Uses the same scenario approach but within a more realistic spatial and temporal framework; key uncertainties are explicitly identified and tested.	At least as good – similar transparency, plus improved structural realism; still precautionary where data are limited.
Outputs & strengths	Species-level annual collision/mortality estimates; good for relative risk ranking and broad comparison between species.	Produces directly comparable species-level outputs and can additionally support parameter sensitivity analysis and future turbine- or habitat-level risk mapping.	Better – delivers all Band-style outputs needed for assessment, plus extra capability for future refinement and mitigation design.
Overall regulatory assurance	Provides continuity with past assessments and a familiar reference point.	Complements Band by reproducing its key patterns under equivalent assumptions while offering a more realistic and flexible site-specific framework.	Suitable alongside Band – New Model is at least as robust as Band and generally more conservative/realistic under shared assumptions.

5.4 Conservation listed species

A total of 27 conservation-significant have been listed for the Pilbara Bioregion under ALA records (**Table 7**). Fifteen of these have medium to high likelihood of being present at Bonney Downs Station.

Three conservation-significant species have been recorded to date at Bonney Downs Station:

- The Grey falcon (*Falco hypoleucos*) **(VU)** is listed as Vulnerable under the EPBC Act and BC Act. There are 83 records of the species in the Pilbara (ALA 2025), and 33 recorded sightings of the Grey falcon during the first 8 BBSUS surveys. Of these, about one third identified the flight height as being sufficient to place the bird in the RSA. **Figure 4** provides the locations at which the Grey falcon was seen. It is likely that some of these may be a single pair. The diagram shows the sightings to be reasonably evenly spread across Bonney Downs site. Both models rated the Grey falcon of being in danger of losing less than 2% of the local population each year due to modelled collision with the WTG. This is a relatively low value (estimated 1 bird collision every ~12 years for the adult population of ~2 pairs), which if correct would mean the population would maintain sustainable levels.

- The Pacific swift (*Apus pacificus*) is a migratory species protected under federal and state legislation **(MI)**. There are 51 records of the species in the Pilbara (ALA 2025), and 12 records at Bonney Downs, all flying below RSA height. We have therefore not carried out CRM for this species as it was never recorded at RSA.

- The Oriental plover (*Charadrius veredus*) is a migratory species protected under federal and state legislation **(MI)**. There are 65 records of the species in the Pilbara (ALA 2025). There has been only one record of this species at Bonney Downs, with the bird flying below RSA height. These data are too few to predict likelihood of turbine collision and we have not carried out CRM for this species.

One conservation-significant species not recorded has a **high** likelihood of occurring at the site, based on habitat suitability (*ecologia* Environment 2025):

- The Peregrine falcon (*Falco peregrinus*) **(OS)** — listed under Western Australian *Biodiversity Conservation Act 2016* as a specially protected species – a species otherwise in need of special protection (other specially protected). There are 120 records of the species in the Pilbara (ALA 2025), but none at Bonney Downs as part of BBSUS. Consequently, without flight height data, we have not carried out CRM for this species.

Two conservation-significant species not recorded have a **medium** likelihood of occurring at the site, based on habitat suitability (*ecologia* Environment 2025).

- Night parrot (*Pezoporus occidentalis*) is protected under international, national and state legislation **(CR)**. These birds usually stay just above vegetation, flying low and fast when flushed, often in zigzag patterns, but have been recorded covering significant distances (18-41 km in a night, Murphy *et al.* 2017) between roosting/feeding sites. There is only 1 record of the species in the Pilbara (ALA 2025) and none at Bonney Downs as part of BBSUS, and we have no flight height data to work from.

- The Glossy ibis (*Plegadis falcinellus*) is a migratory species protected under federal and state legislation. There are 102 records of the species in the Pilbara (ALA 2025), but none at Bonney Downs as part of BBSUS, and we have no flight height data to work from.

Nine migratory waterbird species have been recorded in association with the Fortescue Marsh, but were not recorded at Bonney Downs Station during the BBSUS. These birds have **medium** likelihood of presence at Bonney Downs Station *en route* to the Fortescue Marsh (*ecologia* Environment 2025).

- Australian painted snipe (*Rostratula australis*, **EN**)
- Common greenshank *Tringa nebularia*, **MI**)

- Common sandpiper (*Actitis hypoleucos,* **MI**)
- Sharp-tailed sandpiper (*Calidris acuminata*, **MI**)
- Red-necked stint (*Calidris ruficollis*, **MI**)
- Gull-billed tern (*Gelochelidon nilotica*, **MI**)
- Caspian tern (*Hydroprogne caspia*, **MI**)
- Wood sandpiper *Tringa glareola,* **MI)**
- Marsh sandpiper (Tringa stagnatilis, **MI**)

Other conservation-significant species not recorded have **low** or **no** likelihood of occurring at the site (*ecologia* Environment 2025).

- Southern giant petrel (*Macronectes giganteus*, **EN**)
- Eastern osprey (*Pandion haliaetus*, **MI**)
- Red goshawk (*Erythrotriorchis radiatus*, **EN**)
- Curlew sandpiper (Calidris ferruginea, **CR**)
- Grey wagtail (*Motacilla cinerea*, **MI**)
- Yellow wagtail (*Motacilla flava*, **MI**)
- Princess parrot (*Polytelis alexandrae*, **VU**)
- Letter-winged kite (*Elanus scriptus*)
- Sandhill grasswren (*Amytornis whitei whitei*)
- Barn swallow (*Hirundo rustica*, **MI**)
- Oriental cuckoo (*Cuculus optatus*, **MI**)
- Barking owl (*Ninox connivens*)

Table 7. *List of conservation-significant bird species present in the Pilbara (excluding marine, shorebirds and waders) that are listed under the Threatened and Priority Fauna List (DBCA 2025). The Reid risk rating is based on a much lower RSA (minimum height 30m) and so may inaccurately represent risk for the WTG in this proposal (RSA>100m).*

Common name	Scientific name	National listing†	WA listing§	ALA records in Pilbara§	Likelihood of occurrence at Bonney Downs (Number BBSUS records)	CRM modelled	Reid overall risk CATEGORY
Grey falcon	*Falco hypoleucos*	VU	VU	83	Recorded (33)	Yes	High
Pacific swift	*Apus pacificus*	MI	MI	51	Recorded (12)	No (<RSA)	High
Oriental plover	*Charadrius veredus*	MI	MI	65	Recorded (1)	No (<RSA)	Medium
Peregrine falcon	*Falco peregrinus*	Not listed	OS	120	High (0)	No	High
Night parrot	*Pezoporus occidentalis*	EN	CR	1	Moderate (0)	No	High
Glossy ibis	*Plegadis falcinellus*	MI	MI	102	Moderate (0)	No	High
Australian painted snipe	*Rostratula australis*	EN	EN	320	Moderate (0)	No	High
Common greenshank	*Tringa nebularia*	MI	EN	15678	Moderate (0)	No	High
Common sandpiper	*Actitis hypoleucos*	MI	MI	22877	Moderate (0)	No	Medium
Sharp-tailed sandpiper	*Calidris acuminata*	MI	MI	11307	Moderate (0)	No	High
Red-necked stint	*Calidris ruficollis*	MI	MI	11041	Moderate (0)	No	Medium
Gull-billed tern	*Gelochelidon nilotica*	MI	MI	7177	Moderate (0)	No	High
Caspian tern	*Hydroprogne caspia*	MI	MI	14407	Moderate (0)	No	High
Wood sandpiper	*Tringa glareola*	MI	MI	9017	Moderate (0)	No	Medium
Marsh sandpiper	*Tringa stagnatilis*	MI	MI	7127	Moderate (0)	No	NA[2]
Southern giant petrel	*Macronectes giganteus*	EN	MI	28	Low (0)	No	NA[3]
Eastern osprey	*Pandion haliaetus*	MI	MI	134	Low (0)	No	High
Red goshawk	*Erythrotriorchis radiatus*	EN	VU	584	Low (0)	No	High
Curlew sandpiper	*Calidris ferruginea*	CR	CR	5146	Low (0)	No	High
Grey wagtail	*Motacilla cinerea*	MI	MI	126	Low (0)	No	NA
Yellow wagtail	*Motacilla flava*	MI	MI	0	Low (0)	No	NA
Princess parrot	*Polytelis alexandrae*	VU	P4	1	Low (0)	No	high
Letter-winged kite	*Elanus scriptus*	Not listed	P4	15	Low (0)	No	High
Sandhill grasswren	*Amytornis whitei whitei*†	Not listed	P4	415 (all subspp)	Low (0)	No	Low
Barn swallow	*Hirundo rustica*	MI	MI	11	Low (0)	No	NA
Oriental cuckoo	*Cuculus optatus*	MI	MI	2	Low (0)	No	Medium
Barking owl	*Ninox connivens*	Not listed	P3	7476	Does not occur	No	Medium

Conservation listings

*† Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC) Act (**VU** Vulnerable, **MI** Migratory species protected under international agreement, **EN** Endangered).*

*§ Western Australia Biodiversity Conservation (BC) Act 2016 (**VU** Vulnerable, **MI** Migratory species protected under international agreement, **OS** Species otherwise in need of special protection (other specially protected) under the Biodiversity Conservation Act 2016, **P4** DBCA Priority species, **CR** Critically Endangered).*

***§ ALA Records** Data were downloaded from the Atlas of Living Australia (ALA 2025, 26 December 2025) for the IBRA 6 Pilbara Region (DCCEEW 2023a).*

† sub-species naming according to Black et al. (2020).

[2] *There are 3 other Tringa spp. listed, two with a Medium risk score and one with a High risk score. The ssp with the Medium score are both listed as Least Concern, whereas the spp with the High score is listed as Vulnerable (this is the Common Greenshank). Marsh sandpiper is Least Concern, so in the absence of a Reid 2025 score, Medium would be a best estimation*

[3] *Southern giant petrel is not listed in Reid 2025. However, there are 10 members of the Procellariidae family listed, all with a High risk score*

6 Discussion

The results of two models were compared for 13 bird species that have been determined to spend some time within the height range of the RSA. The Band model has been calibrated to include a bird avoidance of 99.5% (Urquhart & Whitfield 2016). Option 2 of the Band model compared well with the new model with 90% avoidance. This number is obtained from the measured "avoidance" of between 80-95%, described in (Hull & Muir 2013) for the Tasmanian Wedge-tailed eagle. These avoidance factors calibrate to 97-99% avoidance in the Band model (Smales 2023). Similar avoidance calibrations were obtained in Urquhart and Whitfield (2016) for other species.

The two factors that would improve the predictive capability of **all** models are accurate flight height and avoidance information; however, collecting these data would take a considerable amount of time and in many cases may not be possible since it would require GPS or radar tracking of many individuals of each species. This is especially true for those species that are rarely recorded at Bonney Downs Station. Confidence in the outcomes is provided by the fact that the results are consistent between the two models for the number of collisions that might be expected for each species.

There were 15 conservation-significant species with moderate to high likelihood of being present at the site, based on habitat suitability (*ecologia* Environment 2025).

- The Grey falcon (*Falco hypoleucos*) **(VU)** is in danger of losing less than 2% of the local population each year due to modelled collision with the WTG. This is a relatively low value (estimated 1 bird collision every ~12 years for the adult population of ~2 pairs), which if correct would mean the population would maintain sustainable levels. Based on expert elicitation, Reid and Baker (2025) attributed the highest risk profile (class 5) for flight height and second-highest (class 4) for the amount of time spent in flight for this species, with a high overall turbine risk categorisation. However, this assessment estimated threat of collision for an RSA between 30 to 275 m, while the wind farms at Bonney Downs have a much higher RSA (100–280 m) and therefore greater ground clearance (~100m).

- We have not carried out CRM for Pacific swift (*Apus pacificus*) as this species as it was never recorded at RSA. Based on expert elicitation, however, Reid and Baker (2025) attributed the highest risk profile flight height and amount of time spent in flight for this species, with a high overall turbine risk categorisation for this species. However, this assessment estimated threat of collision for an RSA between 30 to 275 m, while the wind farms at Bonney Downs have a much higher RSA (100–280 m) and therefore greater ground clearance (~100m).

- There was a single record of Oriental plover (*Charadrius veredus*) and therefore insufficient data to carry out CRM for this species. Although this species has been attributed by Reid and Baker (2025) attributed 'class 2' for flight height (noting that class 1 was attributed to flightless and resident obligate ground foraging birds), the Oriental plover has been given a score of class 4 for flight time, in recognition of its migration behaviour, with an overall risk categorisation of medium. However, this assessment estimated threat of collision for an RSA between 30 to 275 m, while the wind farms at Bonney Downs have a much higher RSA (100–280 m) and therefore greater ground clearance (~100m).

- Habitat suitability suggests high likelihood of Peregrine falcon (*Falco peregrinus*) **(OS)**, although there were no records as part of BBSUS. Consequently, without flight height data, we have not carried out CRM for this species. Based on expert elicitation, Reid and Baker (2025) attributed the highest risk profile flight height (class 5) and second-highest categorisation (class 4) for amount of time spent in flight for this species, with a high overall turbine risk categorisation. However, this assessment estimated threat of collision for an RSA between 30 to 275 m, while the wind farms at Bonney Downs have a much higher RSA (100–280 m) and therefore greater ground clearance (~100m).

- Night parrot (*Pezoporus occidentalis*) have not been recorded at Bonney Downs as part of BBSUS, and we have no flight height data to work from. From expert elicitation, Reid and Baker (2025) classed this species as likely to have a low chance of flying within RSA height (class 2, noting that class 1 was attributed to flightless and resident obligate ground foraging birds). Based on these assessments, the species would have low likelihood of turbine collision. However, Night parrots have been classed as having high risk of wind energy developments, overall, largely due to their habitat specialisation and conservation ranking (Reid & Baker 2025). However, this assessment estimated threat of collision for an RSA between 30 to 275 m, while the wind farms at Bonney Downs have a much higher RSA (100–280 m) and therefore greater ground clearance (~100m).

- The Glossy ibis (*Plegadis falcinellus*) have not been recorded at Bonney Downs as part of BBSUS, and we have no flight height data to work from. From expert elicitation, this ibis has been grouped as class 4 for habitat specialisation and class 4 for flight height, classified as high overall turbine risk (Reid & Baker 2025). However, this assessment estimated threat of collision for an RSA between 30 to 275 m, while the wind farms at Bonney Downs have a much higher RSA (100–280 m) and therefore greater ground clearance (~100m).

For nine migratory waterbirds associated with Fortescue Marsh (but not recorded at Bonney Downs during the BBSUS), Reid and Baker (2025) Appendix 4 outlines the following overall risk categories:

- Australian painted snipe (*Rostratula australis*) – High
- Caspian tern (*Hydroprogne caspia*) – High
- Common greenshank (*Tringa nebularia*) – High
- Common sandpiper (*Actitis hypoleucos*) – Medium
- Gull-billed tern (*Gelochelidon nilotica* [incl. *G. n. affinis*]) – High
- Marsh sandpiper (*Tringa stagnatilis*) – was not assigned an overall risk category in Appendix 4; so no Reid & Baker overall risk category is available for this species.
- Red-necked stint (*Calidris ruficollis*) – Medium
- Sharp-tailed sandpiper (*Calidris acuminata*) – High
- Wood sandpiper (*Tringa glareola*) – Medium

These nine migratory birds have **medium** likelihood of presence at Bonney Downs Station *en route* to the Fortescue Marsh (*ecologia* Environment 2025).

The Reid and Baker (2025) Appendix 4 risk categories are a national, trait-based screening outcome that relies heavily on susceptibility attributes such as time spent flying and flight height relative to the rotor-swept area, and Reid & Baker note that empirical Australian flight-altitude data are limited for many taxa. At Bonney Downs, the lower bound of the rotor-swept area is substantially higher than the minimum rotor heights assumed in many generic onshore wind assessments (e.g., commonly spanning ~30 to >130 m in guidance examples), which means the proportion of flights occurring within the rotor-risk height band could be lower for some wetland-associated species if their local movements are predominantly at low altitude (NatureScot 2025). More broadly, studies using the Band framework show that increasing ground clearance can materially reduce collision risk for species whose flight-height distribution is concentrated below the lower rotor sweep (Schaub *et al.* 2024a). In addition, these Fortescue Marsh-associated taxa may be encountered at Bonney Downs primarily during intermittent commuting or passage movements rather than regular foraging/loafing activity within the development envelope; accordingly, their site-specific collision risk category may differ from national screening categories once site-specific data on passage frequency and flight-height distributions (including commuting trajectories) are available.

6.1 Conclusions

HBI developed and applied a three-dimensional, time-explicit collision risk model (the New Model) in parallel with the Band model to assess turbine-collision risk at the Bonney Downs Wind Farm. The New Model preserves Band's core collision geometry but simulates individual bird trajectories in three dimensions across the actual turbine layout and explicitly quantifies time spent in the rotor-swept airspace (RSA). Run for 13 bird species recorded flying within the RSA, the New Model reproduces the Band model's relative risk ranking (strong correlation reported between

Band Option 2 and the New Model under comparable avoidance scenarios) while providing improved structural realism for a large, spatially complex array.

HBI's analysis and Bonney Downs survey outputs indicate that the following conservation-listed taxa are present within the study area and warrant targeted attention:

- Grey falcon (*Falco hypoleucos*) **(VU)**. Band Model results: ≈1.86% p.a. (99.5% avoidance) or New Model results: ≈1.61% p.a. (90% avoidance). The worst-case prediction is 5.05% (98% avoidance), which would equate to 1 adult every 5 years. These are relatively low values, which if correct would mean the population would maintain sustainable levels. The values are reported as conservative inherent (unmitigated) collision risk estimates given the deliberately precautionary inputs used where species-specific data are limited.

HBI emphasises that these numerical results should be treated with caution. The New Model's structural advances (explicit array layout and 3-D movement) give it at least equivalent — and in relevant respects superior — inferential capacity compared with the Band model, but both approaches remain dependent on a small number of influential inputs (notably: proportion of time in the RSA, time in the air and avoidance behaviour). Under equivalent inputs the New Model produces species-level outputs that are comparable with those from Band; consequently, the two models together provide an appropriately cautious basis for assessment of the listed taxa.

7 References

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8 Appendix

8.1 Turbine Data

The configuration proposed for the Bonney Downs project, and used as the basis of simulations, is given in **Table A7** and **Table A8**. The potential locations of the 117 turbines are given in **Figure A8**.

Table A8. *Specifications of the proposed Bonney Downs Wind Farm and the Nullagine Pilot Wind Farm.*

Technical Information and Wind Farm Component	Data used/Scenario Modelled
Turbine model	Envision Energy EN182-7.8
Number of turbines	17 for Nullagine pilot project, 100 for Bonney Downs wind farm
Number of blades per turbine rotor	3
Rotor blade maximum chord (m) (i.e., depth of blade)	4.897 m
Blade Length (m)	89 m
Rotor Radius (m)	91 m
Rotor Diameter (m)	182m
Circumference of blade tip (m) (Pi x Rotor Diameter)	571.77 m
Swept area (m^2) (Pi x Rotor Radius^2)	26,015.53 m^2
Turbine height (m)	279 m
Hub height (m)	188 m
Swept height (m)	182 m
Maximum height to blade tip (m)	279 m
Minimum height to blade tip (m)	97 m
Max Tip Speed (m/s)	89.58 m/s
Rotation speed (rpm)	Varies from 3.3 rpm at 3 m/s to 9.4 rpm at 9.5 m/s and then constant at 9.4 rpm up until cut-out (25 m/s)
Rotation period (s) (i.e., seconds per rotation)	6.38 s for 9.4 rpm, 18.18 s for 3.3 rpm
Turbine operation time	Operate between 95-98% of the time.
Mean pitch angle of the blade during normal operation (degrees)**	Probably -5 deg up until rated wind speed at 14 m/s and then steadily increases to around 25 deg at cut-out (25 m/s). Parked at 90 degrees.

*** The pitch angle of the turbine blade is determined by wind speed, which is variable depending on several factors including, location, local topographic, landscape etc. To maintain a constant operating speed the pitch angle of the blade is altered. The pitch angle of the turbine blade is greater in stronger winds to "feather" the blades to control rotation speed.*

Table A9. *Rotor speed as a function of wind speed for the proposed turbines. Given wind data, the average speed of the rotor over the year can be incorporated into the model.*

Hub height wind speed [m/s]	Rotor speed [RPM]
3	3.3
3.5	3.8
4	4.3
4.5	4.9
5	5.4
5.5	5.9
6	6.5
6.5	7.0
7	7.6
7.5	8.1
8	8.6
8.5	9.0
9	9.3
9.5	9.4
Greater than 10	9.4

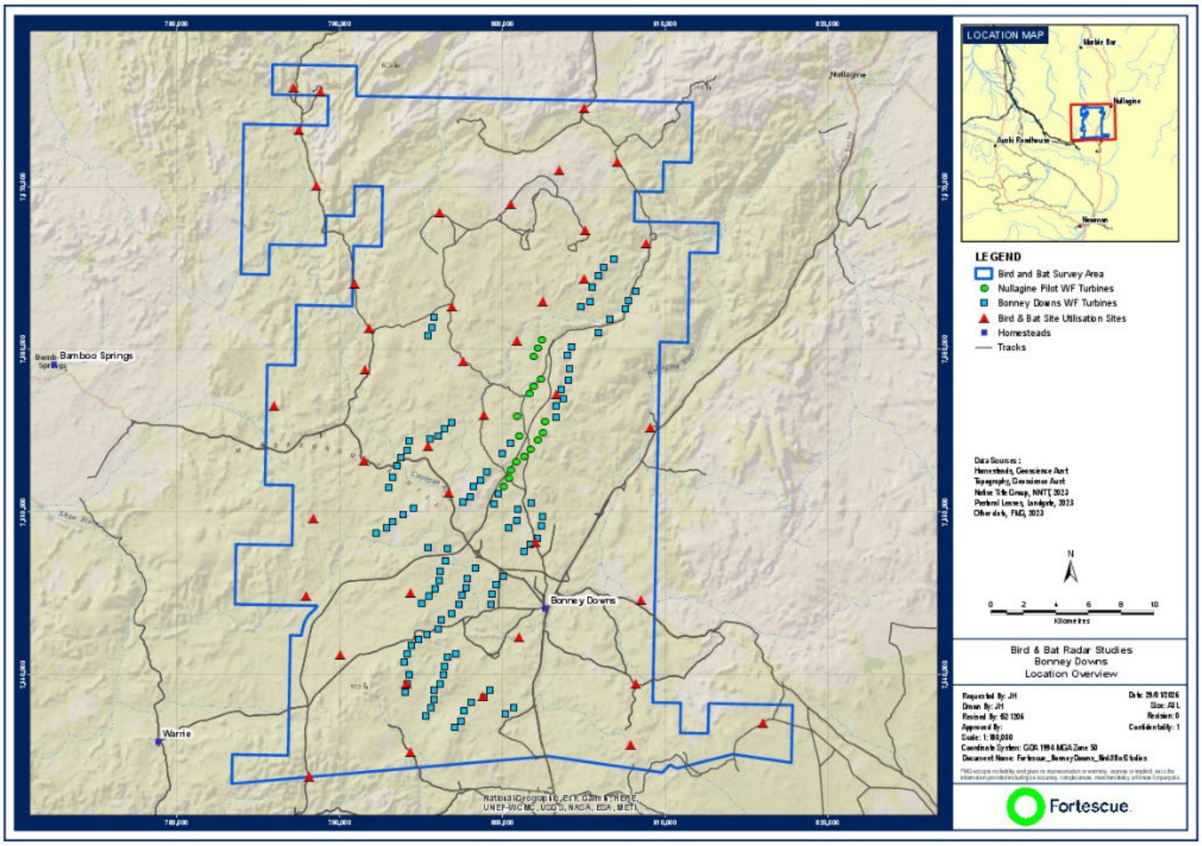

Figure A8. *Proposed location of turbines (blue) and BBSUS sites(red) with Pilot WTG (green).*