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Comparison of potential collision risk for birds of four different wind turbines for Flinders Island, Tasmania

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Biosis Research

Natural & Cultural Heritage Consultants 38 Bertie Street (PO Box 489) Port Melbourne Victoria 3207

Report for
Hydro Tasmania Consulting

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Ian Smales

Melbourne: *38 Bertie Street Port Melbourne 3207*
Ph: (03) 9646 9499 Fax: (03) 9646 9242
email: melbourne@biosisresearch..com.au

Ballarat: *449 Doveton Street North, Ballarat VIC 3350*
Ph: (03) 5331 7000 Fax: (03) 5331 7033
email: ballarat@biosisresearch..com.au

Queanbeyan: *55 Lorn Road, Queanbeyan NSW 2620*
Ph: (02) 6284 4633 Fax: (02) 6284 4699
email: queanbeyan@biosisresearch..com.au

Sydney: *15-17 Henrietta Street, Chippendale NSW 2008*
Ph: (02) 9690 2777 Fax: (02) 9690 2577
email: sydney@biosisresearch.com.au

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1.0 INTRODUCTION

Hydro Tasmania Business Development is assessing the potential to add capacity to existing wind power electricity generation at Flinders Island. It is proposed to commission up to a maximum of four new turbines for the purpose.

As part of that evaluation, Biosis Research was commissioned by Hydro Tasmania Business Development to compare the potential collision risks posed to birds by four different makes and models of wind turbines. The actual manufacturer and model of turbines that might be employed at Flinders Island is likely to depend upon availability and/or other factors and the four turbines modelled here are examples representing the range from minimum to maximum of turbine sizes that might be utilised. Consequently, the predictions of avian collision risk provide here cover the expected range from minimum to maximum within which actual risk posed by the turbine selected is considered likely to fall.

The Biosis Research Deterministic Collision Risk Model was used to provide predictions of annual movements at risk for all birds for which data is available.

2.0 METHODOLOGY

Modelling was undertaken using data for bird movements obtained during timed fixed-point counts at Flinders Island during 2003. Methods used in fixed point utilisation surveys were as per those outlined in Organ and Meredith (2004) and were formally agreed between the proponent and DPIWE (now DPIW) in 2003. The model used for these estimates is the revised Biosis Research Deterministic Collision Risk Model. The four turbine types differ from each other in various aspects including dimensions of various components, number of rotors and rotor speeds. In order to incorporate these differences each was modelled separately

2.1 Input values used in collision risk modelling

Modelling of the risk of bird collisions with the various turbines has been undertaken using the Biosis Research Deterministic Collision Risk Model.

Four different turbine types have been selected by Hydro Tasmania Business Development to represent the size range and generating capacity of machines that might be used in expansion of the current renewable power generation for Flinders Island. Predictions of collision risks associated with the four machines modelled here are thus considered to represent the upper and lower bounds within which the actual risks of whatever turbine is selected will fall. The turbine type that will actually be used has not yet been determined, however at least one turbine modelled here, the Vergnet 275, is not under consideration for Flinders Island (R. Grant, Hydro Tasmania pers. comm.)

The four turbine types evaluated here are:

- Enercon E33
- Vergnet 275
- Vestas V52
- Windflow 500

Specifications for each turbine were as provided by turbine manufacturers and supplied to Biosis Research by Hydro Tasmania Business Development. These included dimensions of components, number of rotor blades and rotor speeds. Note that some dimensions were not supplied and were estimated. Where possible the estimates were scaled from available photographs of the relevant machine.

The model uses data on the flight activity for each species of bird for the site. Bird activity is quantified as a 'utilisation rate' for each species. Utilisation data was obtained during a regime of fixed-time point counts and the methodology employed was formally agreed between the proponent and DPIWE (now DPIW) in 2003. Counts were undertaken in 2003 in the area where it is proposed to site additional turbines. These data include flights within the range of heights of the four turbines for 23 species of birds and a further three groups of species, such as 'unidentified raptors'. Data for 'unidentified raven' is here considered to represent records of the Forest Raven.

A variety of values for all of the following parameters, provide inputs to the collision risk model:

a. Data for the numbers of flights each bird species may make below rotor height, and for which just the lower portion of the turbine towers present a collision risk, collected during timed point counts.

b. Data for the numbers of bird flights that may occur at heights within the zone swept by the turbine rotors, and for which the moving rotor blades present a collision risk, collected during timed point counts.

The total turbine height and the height zone swept by rotors differ between the four turbines evaluated here. Flight height data for each species of bird was sorted into the appropriate height categories to equate with the relevant heights for each of the four turbines.

c. The annual numbers of movements-at-risk of collision. This parameter is based upon the data recorded for each species during timed point count surveys (as per parameters a) and b) above), which are then extrapolated to determine an estimated number of movements-at-risk for each species for an entire year. Account is also taken of whether particular bird species are year-round residents or annual migrants that may be either seasonally resident or simply pass through the site. Point counts encompassed a total of 2610 minutes of observation.

d. The mean area (m^2 per turbine) of the tower, nacelle and stationary rotor blades of a wind generator that present a risk to birds. In most instances involving resident birds a multidirectional model is used which allows for birds to move toward a turbine from any direction. The mean area presented by a turbine is determined to be between the maximum (where the direction of the bird is perpendicular to the plane of the rotor sweep) and the minimum (where the direction of the bird is parallel to the plane of the rotor sweep). The mean presented area is normally determined from turbine manufacturer's specifications provided for individual turbine makes and models.

e. The additional area (m^2 per turbine) presented by the movement of rotors during the potential flight of a bird through the zone swept by turbine rotors. This is determined according to the rotational speed of the turbine blades and the body length and flight speed of the bird species in question. Since this parameter is determined by the time required for forward flight by a bird through the rotor zone, the bird the dimension used is body length, rather than any other dimension(s) of the bird.

f. A calculation, based on the layout and total number of turbines proposed for a wind farm, of the number of turbines likely to be encountered by a bird in any one flight. This differs according to whether turbines are aligned in a linear or a clustered array on the landscape. For all turbines modelled here it was assumed that four machines would be set out in a cluster. The generating capacity represented by the four different types of machines modelled here varies considerably and some of such turbines may exceed power generation requirements if four were built. It is thus feasible that fewer than four generators would be built if such higher capacity machines were selected (R. Grant, Hydro Tasmania pers. comm.). Four machines is therefore considered to be the maximum that might be used.

In early 2005 the Biosis Research Deterministic Collision Risk Model was updated to incorporate refinements to parameters (d) and (e), above. These refine the way that bird avoidance behaviour is modelled for the static and dynamic or moving components of a turbine. For (e), the adjustment also allows the body length and, where available, flight speed of a given species of bird to be used. In previous versions of the model each species of bird was assigned to one of four arbitrary categories of bird length and flight speed.

2.2 Collision avoidance behaviour

The model also provides a measure of the potential risk at different rates at which birds might avoid collisions. A 90% avoidance rate means that in one of every ten flights a bird would not avoid an obstacle in its path. Clearly, most birds have vastly better avoidance capacity than this and it is well established overseas that even collision-prone bird species avoid collisions with wind generators on most occasions (Winkelman 1992; Still *et al*. 1994). We consider that avoidance rates above 98% are 'ecologically reasonable' for most species in most circumstances. Nonetheless, the different species of birds present at any site are likely to have different capacities to avoid collisions and some species of birds may have lower avoidance rates due to their flight behaviours. Since the avoidance capacity exhibited by particular species requires confirmation based on actual experience, we provide results for a range of avoidance rates for all species.

In modelling results presented here the risk is divided into two height zones according to components of wind turbine structures. These are:

1. the stationary tower below rotor height, and

2. the turbine components within the height area swept by turbine rotors

We consider that birds will avoid collision with the stationary tower below rotor height in all but the most exceptional circumstances and model for 99% avoidance rate in that height zone. For the zone within rotor-swept height (encompassing rotors, upper portion of tower and nacelle) we provide predictions for movements at risk for each of 90%, 98% and 99% avoidance rates.

2.3 Output values of collision risk modelling

Outputs of the model are provided in terms of the annual average number of flights that pose a risk of collision for all bird species. Note that this does not necessarily equate to the number of bird deaths that might occur.

It is possible to predict mortalities from the model only for species whose population size for the site is either known or can be accurately estimated. That is not the case for the majority of the bird species at Flinders Island that are modelled here. The Tasmanian Wedge-tailed Eagle is the only threatened species for which there is both sufficient utilisation data and information on which to base an estimated number of birds that might interact with turbines at the proposed site. On the basis of that information, predictions of average annual mortalities are provided for this species.

3.0 CONSERVATION STATUS OF BIRDS

Two pieces of legislation are relevant to an assessment of impacts on birds at Flinders Island. Species that are afforded particular protection due to their conservation status are listed under provisions of Tasmania's *Threatened Species*

Protection Act 1995 (*TSP Act*) and the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (*EPBC Act*).

The *TSP Act* and provisions of the *EPBC Act* for threatened species provide listings of species according to various categories of threat. The *EPBC Act* also has particular provisions for species listed as 'migratory' and as 'marine'. Provisions for migratory species cover Australia's obligations under three international treaties and conventions for conservation of such fauna. The provisions for marine species cover Commonwealth marine areas and actions that may have a significant impact on the environments of such areas.

The conservation status of species that were recorded during counts and that are listed under this legislation is shown in Table 1.

Table 1. Conservation status of birds recorded during point counts.

Common name	Scientific name	Status Tasmania (TSP Act)	Status Commonwealth (EPBC Act)		
			Threatened Species	Migratory	Marine
Cape Barren Goose	*Cereopsis novaehollandiae*				✓
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	Vulnerable		✓	✓
Tasmanian Wedge-tailed Eagle	*Aquila audax fleayi*	Endangered	Endangered		
Pacific Gull	*Larus pacificus*				✓
Kelp Gull	*Larus dominicanus*				✓

Since the proposed wind farm is not in a Commonwealth marine area and is not likely to have a significant impact on the environments of any Commonwealth marine area, any impacts on birds resulting from the proposal are not considered likely to trigger provisions of the *EPBC Act* for 'marine' species.

Two species of birds recorded during point counts are listed under categories of threat by the *TSP Act* and/or the *EPBC Act*. They are the White-bellied Sea-Eagle and Tasmanian Wedge-tailed Eagle. The White-bellied Sea-Eagle is also listed under provisions of the *EPBC Act* for 'migratory' species. Further consideration is given to these two threatened species in the risk assessment below (Section 4.2).

4.0 COMPARATIVE COLLISION RISKS OF FOUR TURBINE TYPES

4.1 Risk to all bird species

At the outset it is worth noting that the collision risk estimates for all bird species are very low for the types of turbines represented by the four turbines assessed here when compared to the risks to the same species posed by larger turbines at various locations in south-eastern Australia. This may reflect lower numbers of birds at the Flinders Island site in addition to the smaller size and low number of turbines proposed to be used there.

The collision risk posed by the different turbines varies between species for a variety of reasons. These include such things as the propensity for a given species to fly below or within the height zone swept by rotors and the interaction of the species' body length and the revolution speed of rotors, which in turn dictate the length of time a bird might take to pass through the rotor-swept zone. Factors such as overall height, rotor span and revolution speed differ between the four turbines.

Detailed model results for all species and for each of the four turbines assessed are provided in Appendix 1. They show the annual average number of movements by all species that are at risk of collision. For each turbine type, totals of the numbers of movements at risk for all bird species are provided at the foot of each table in Appendix 1. Numbers of movements at risk do not necessarily equate to a prediction of the number of birds that might be killed.

In general, the results indicate that small turbines present a lower overall risk to birds than that posed by larger turbines. However, collision risk is not correlated with the size of machines alone. A higher overall level of predicted risk is also associated with machines whose rotor swept zone is closer to the ground than that of other turbines. It occurs because more flights by a greater range of bird species occur relatively lower, rather than higher, above the ground. In the examples modelled, this effect is exemplified by the higher risk estimates for the Windflow 500 turbine which has a rotor-swept zone extending from 13.4 – 46.6 metres above the ground as compared to turbines with a similar extent of rotor sweep but which is positioned higher above the ground.

4.2 Risk to threatened species

Specific estimates of collision risk for two threatened species are highlighted in the tables in Appendix 1. These provide the comparative estimate of risk for each of those species for the four different turbines.

4.2.1 White-bellied Sea-eagle

Predictions of the annual number of movements at risk of collision for the White-bellied Sea-eagle (Appendix 1) are based on a single flight by an eagle observed during point counts. The flight was below the rotor-swept height of all four turbine types and thus the predicted annual number of movements at risk of collision for this species simply reflects a risk of collision with the static tower below the rotors. In modelling of the risk of birds hitting this large static object it is considered reasonable that they will avoid a collision in virtually all cases and thus a 99% avoidance rate is applied for this component of all turbines, as outlined in Section 2.2.

Since the site proposed for the turbines is approximately 3.5 kilometres from the coast, the low level of White-bellied Sea-eagle activity recorded during point counts is in accord with the habitat preferences of the species. At wind farm sites elsewhere in Tasmania, such as Woolnorth and Musselroe, the species' activity has been documented to be strongly associated with the coastline. The flight data for this species suggests that it is at minimal risk of collision with turbines proposed for Flinders Island. The data is not sufficient to validly model for an estimated annual number of fatalities.

4.2.2 Tasmanian Wedge-tailed Eagle

Estimated annual numbers of movements at risk of collision for the Tasmanian Wedge-tailed Eagle are shown in the tables in Appendix 1. The results suggest that for this species height above the ground of rotors has relatively little influence on risk. This is because these eagles fly within a wide range of heights from ground level to very much higher than the maximum height of all four turbines modelled here. They routinely fly at greater heights than most of the other species modelled here. Thus, within the range of turbines modelled here, the predicted collision risks for Wedge-tailed Eagles relates primarily to the simple sizes of machines, with smaller turbines presenting lower risk and larger turbines presenting higher risk.

The bird utilisation data for Wedge-tailed Eagles is sufficient, in combination with an estimate of numbers of the species that might interact with turbines, to model for a prediction of an annual average number of fatalities. The following rationale has been used to estimate the size of the eagle's population that might interact with the turbines.

During the annual breeding season mature Wedge-tailed Eagles defend a core part of their home-range centred on the nest, however other Wedge-tailed Eagles are often tolerated over the majority of a pair's home-range. Non-breeding birds may utilise habitat outside of the home-ranges of breeding birds. It is usual for Wedge-tailed Eagles to fledge one juvenile per annum.

Tasmania's Natural Values Atlas (GT Spot database) has records of nine Wedge-tailed Eagle nest sites on Flinders Island (Table 2) (*cf*. an estimated 1 – 2 pairs of breeding birds in Furneaux Group (Mooney 1984)). Three of the nest sites are within a radius of 10 kilometres of the wind farm site.

Table 2. Records of Tasmanian Wedge-tailed Eagle nest sites on Flinders Island (Natural Values Atlas data, 12/12/06). Sites within 10 km of proposed turbines highlighted.

Nest record (GTSpot Reference)	Location	MGA Easting	MGA Northing	Distance to wind farm (km)
tp:rn:49/1	South Patriarch	602881	5571399	20
tp:rn:50/1	***Counsels Peak***	***594448***	***5560090***	***6***
tp:rn:53/1	***The Dutchman***	***599533***	***5557810***	***10***
tp:rn:54/1	Mount Belstead	592997	5546620	11
tp:rn:55/1	Mount Razorback	592814	5544578	12
tp:rn:33/1	Mount Blyth	578576	5592012	37
tp:rn:42/1	Mount Bramich	603153	5574200	22
tp:rn:46/1	Brougham Sugarloaf	585147	5567549	12
tp:rn:871/1	***Walkers Lookout Road***	***590112***	***5564783***	***8***

For the purposes of this modelling exercise it is assumed that all of the known Wedge-tailed Eagle territories on the island are occupied in a given year and thus that the three within ten kilometres of the wind farm site are also active. On the assumption that the home-ranges of all three of the pairs represented by nest sites within ten kilometres of the wind farm might overlap, and with the additions of their offspring and a few non-breeding sub-adults, it would seem feasible that up to twelve individuals could move within the wind farm site in a given year.

Comparison of modelled predictions of average annual mortality and actual fatalities of Tasmanian Wedge-tailed Eagles has recently been assessed following four years of experience at the Bluff Point Wind Farm in north-west Tasmania (Smales 2007). That experience suggests that the species has a collision avoidance capacity for the dynamic components of turbines of about 90%.

Running the collision risk model for an annual population of twelve Wedge-tailed Eagles provides the estimates of annual average numbers of eagle deaths shown in Table 3.

Table 3. Predicted mean number of Wedge-tailed Eagle mortalities per annum for four turbines on Flinders Island. Results for four different turbine types are shown for three percentage avoidance rates and assuming that 12 birds might be present at the site within a given year.

	Mean number of WTE mortalities per annum predicted at three avoidance rates		
	90%	**98%**	**99%**
Enercon E33	0.037	0.017	0.014

Vergnet 275	0.016	0.009	0.008
Vestas V52	0.066	0.023	0.018
Windflow 500	0.029	0.012	0.010

By comparison with annual mortality estimates for most other wind farm proposals in southern Australia the predictions are for very low numbers of Wedge-tailed Eagle deaths. This is likely to reflect the small number of Wedge-tailed Eagle flights observed during point counts, in combination with the small size and low number of turbines proposed for Flinders Island.

In this instance the model's predictions for annual numbers of mortalities are the same as the annual numbers of movements at risk of collision. This is due to the low level of observed activity for an assumed population of twelve birds. Essentially, the predicted collision risks of Wedge-tailed Eagle deaths for the four turbine types correlates with the size of turbines, from smallest to largest turbine type.

5.0 CONCLUSION

Risk estimates, measured as an annual number of movements at risk of collision, are provided for the suite of bird species recorded during point counts and specifically for two threatened species.

The comparative risk estimates of collisions with all four potential turbine types are low by comparison with larger turbines at other locations in south-eastern Australia.

For the entire suite of bird species recorded during point counts, including two threatened species, and for the range of turbine specifications exemplified by the four machines modelled here, the evaluation suggests that small machines with rotors set higher above the ground present the lowest collision risk.

A prediction of annual average number of mortalities has been made, based on information and some assumptions about the local population, for the Tasmanian Wedge-tailed Eagle. By this assessment, the risks associated with installing four of each of the turbine types indicate that for this species the worst case scenario results in a risk of the death of 0.066 eagles per annum.

As noted at the outset, the four machines modelled here provide representative examples for the range of different sized machines under consideration by Hydro Tasmania for the proposed expansion of generating capacity at Flinders Island. It is possible that less than four turbines would be built if, within the range represented by the turbines modelled here, larger turbines with higher generating capacity were to be selected. In that case, the risks to birds for those types of machines would be lower than those predicted here. The predictions of collision risks associated with the four machines modelled here are thus considered to represent the upper and lower bounds within which the actual risks of whatever turbine is selected will fall.

APPENDICES

APPENDIX 1

A1.1 Risk Modelling - bird movements at risk

Note: values in the following tables provide a prediction of the annual average number(s) of movements made by each species that pose a risk of collision. They should not be confused with predictions of the numbers of potential mortalities that might occur.

Table A1.1: Numbers of bird movements per annum at risk of collision with 4 Enercon E33 turbines.

Movements at risk are shown for potential collisions with turbine towers below rotor-swept height and within rotor-swept area assuming a 99% avoidance of stationary tower and three avoidance rates within rotor-swept area.

Common name	Scientific name	Dynamic Avoidance Rate		
		90%	98%	99%
Cape Barren Goose	*Cereopsis novaehollandiae*	0.016	0.016	0.016
Australian Shelduck	*Tadorna tadornoides*	0.014	0.014	0.014
White-bellied Sea-Eagle	***Haliaeetus leucogaster***	**0.002**	**0.002**	**0.002**
Swamp Harrier	*Circus approximans*	0.007	0.007	0.007
Wedge-tailed Eagle	***Aquila audax fleayi***	**0.037**	**0.017**	**0.014**
Brown Falcon	*Falco berigora*	0.337	0.156	0.133
Nankeen Kestrel	*Falco cenchroides*	0.283	0.173	0.159
Pacific Gull	*Larus pacificus*	1.557	0.621	0.504
Kelp Gull	*Larus dominicanus*	0.035	0.009	0.006
Green Rosella	*Platycercus caledonicus*	0.073	0.073	0.073
Superb Fairy-wren	*Malurus cyaneus*	0.009	0.009	0.009
White-fronted Chat	*Epthianura albifrons*	0.045	0.045	0.045
Australian Magpie	*Gymnorhina tibicen*	0.426	0.405	0.402
Black Currawong	*Strepera fuliginosa*	1.334	0.824	0.760
Forest Raven	*Corvus tasmanicus*	0.415	0.290	0.275
Skylark	*Alauda arvensis*	1.849	0.901	0.783
Richard's Pipit	*Anthus novaeseelandiae*	0.557	0.183	0.136
House Sparrow	*Passer domesticus*	0.025	0.025	0.025
European Goldfinch	*Carduelis carduelis*	0.118	0.118	0.118
Welcome Swallow	*Hirundo neoxena*	0.002	0.002	0.002
Silvereye	*Zosterops lateralis*	0.014	0.014	0.014
Common Blackbird	*Turdus merula*	0.027	0.027	0.027
raptor sp.		0.060	0.026	0.022
unidentified passerine		0.050	0.050	0.050
gull sp.		0.068	0.068	0.068
Total annual movements at risk for all birds		**7.362**	**4.077**	**3.666**

Table A1.2: Numbers of bird movements per annum at risk of collision with 4 Vergnet 275 turbines.

Movements at risk are shown for potential collisions with turbine towers below rotor-swept height and within rotor-swept area assuming a 99% avoidance of stationary tower and three avoidance rates within rotor-swept area.

Common name	Scientific name	Dynamic Avoidance Rate		
		90%	98%	99%
Cape Barren Goose	*Cereopsis novaehollandiae*	0.011	0.011	0.011
Australian Shelduck	*Tadorna tadornoides*	0.009	0.009	0.009
White-bellied Sea-Eagle	***Haliaeetus leucogaster***	**0.002**	**0.002**	**0.002**
Swamp Harrier	*Circus approximans*	0.005	0.005	0.005
Wedge-tailed Eagle	***Aquila audax fleayi***	**0.016**	**0.009**	**0.008**
Brown Falcon	*Falco berigora*	0.117	0.074	0.068
Nankeen Kestrel	*Falco cenchroides*	0.111	0.094	0.092
Pacific Gull	*Larus pacificus*	0.487	0.285	0.260
Kelp Gull	*Larus dominicanus*	0.002	0.002	0.002
Green Rosella	*Platycercus caledonicus*	0.048	0.048	0.048
Superb Fairy-wren	*Malurus cyaneus*	0.006	0.006	0.006
White-fronted Chat	*Epthianura albifrons*	0.030	0.030	0.030
Australian Magpie	*Gymnorhina tibicen*	0.274	0.267	0.266
Black Currawong	*Strepera fuliginosa*	0.550	0.472	0.462
Forest Raven	*Corvus tasmanicus*	0.219	0.179	0.174
Skylark	*Alauda arvensis*	0.586	0.460	0.445
Richard's Pipit	*Anthus novaeseelandiae*	0.185	0.078	0.065
House Sparrow	*Passer domesticus*	0.017	0.017	0.017
European Goldfinch	*Carduelis carduelis*	0.079	0.079	0.079
Welcome Swallow	*Hirundo neoxena*	0.002	0.002	0.002
Silvereye	*Zosterops lateralis*	0.009	0.009	0.009
Common Blackbird	*Turdus merula*	0.018	0.018	0.018
raptor sp.		0.019	0.012	0.011
unidentified passerine		0.033	0.033	0.033
gull sp.		0.045	0.045	0.045
Total annual movements at risk for all birds		**2.879**	**2.245**	**2.166**

Table A1.3: Numbers of bird movements per annum at risk of collision with 4 Vestas V52 turbines.

Movements at risk are shown for potential collisions with turbine towers below rotor-swept height and within rotor-swept area assuming a 99% avoidance of stationary tower and three avoidance rates within rotor-swept area.

Common name	Scientific name	Dynamic Avoidance Rate		
		90%	98%	99%
Cape Barren Goose	*Cereopsis novaehollandiae*	0.014	0.014	0.014
Australian Shelduck	*Tadorna tadornoides*	0.012	0.012	0.012
White-bellied Sea-Eagle	***Haliaeetus leucogaster***	**0.002**	**0.002**	**0.002**
Swamp Harrier	*Circus approximans*	0.025	0.011	0.009
Wedge-tailed Eagle	***Aquila audax fleayi***	**0.066**	**0.023**	**0.018**
Brown Falcon	*Falco berigora*	0.460	0.188	0.154
Nankeen Kestrel	*Falco cenchroides*	0.415	0.201	0.174
Pacific Gull	*Larus pacificus*	2.455	0.807	0.601
Kelp Gull	*Larus dominicanus*	0.039	0.010	0.007
Green Rosella	*Platycercus caledonicus*	0.062	0.062	0.062
Superb Fairy-wren	*Malurus cyaneus*	0.008	0.008	0.008
White-fronted Chat	*Epthianura albifrons*	0.039	0.039	0.039
Australian Magpie	*Gymnorhina tibicen*	0.493	0.376	0.362
Black Currawong	*Strepera fuliginosa*	2.839	1.111	0.896
Forest Raven	*Corvus tasmanicus*	0.467	0.276	0.252
Skylark	*Alauda arvensis*	3.169	1.130	0.875
Richard's Pipit	*Anthus novaeseelandiae*	0.612	0.191	0.138
House Sparrow	*Passer domesticus*	0.021	0.021	0.021
European Goldfinch	*Carduelis carduelis*	1.557	0.426	0.284
Welcome Swallow	*Hirundo neoxena*	0.002	0.002	0.002
Silvereye	*Zosterops lateralis*	0.012	0.012	0.012
Common Blackbird	*Turdus merula*	0.023	0.023	0.023
raptor sp.		0.081	0.032	0.025
unidentified passerine		0.232	0.088	0.070
gull sp.		0.058	0.058	0.058
Total annual movements at risk for all birds		**13.163**	**5.124**	**4.120**

Table A1.4: Numbers of bird movements per annum at risk of collision with 4 Windflow 500 turbines.

Movements at risk are shown for potential collisions with turbine towers below rotor-swept height and within rotor-swept area assuming a 99% avoidance of stationary tower and three avoidance rates within rotor-swept area.

Common name	Scientific name	Dynamic Avoidance Rate		
		90%	**98%**	**99%**
Cape Barren Goose	*Cereopsis novaehollandiae*	0.133	0.040	0.028
Australian Shelduck	*Tadorna tadornoides*	0.076	0.026	0.019
White-bellied Sea-Eagle	***Haliaeetus leucogaster***	**0.001**	**0.001**	**0.001**
Swamp Harrier	*Circus approximans*	0.052	0.019	0.015
Wedge-tailed Eagle	***Aquila audax fleayi***	**0.029**	**0.012**	**0.010**
Brown Falcon	*Falco berigora*	0.246	0.112	0.095
Nankeen Kestrel	*Falco cenchroides*	0.580	0.252	0.211
Pacific Gull	*Larus pacificus*	2.343	0.753	0.554
Kelp Gull	*Larus dominicanus*	0.031	0.009	0.006
Green Rosella	*Platycercus caledonicus*	0.047	0.047	0.047
Superb Fairy-wren	*Malurus cyaneus*	0.006	0.006	0.006
White-fronted Chat	*Epthianura albifrons*	0.167	0.069	0.056
Australian Magpie	*Gymnorhina tibicen*	0.771	0.394	0.347
Black Currawong	*Strepera fuliginosa*	2.769	1.038	0.822
Forest Raven	*Corvus tasmanicus*	0.501	0.247	0.215
Skylark	*Alauda arvensis*	4.571	1.399	1.002
Richard's Pipit	*Anthus novaeseelandiae*	0.373	0.120	0.088
House Sparrow	*Passer domesticus*	0.462	0.124	0.082
European Goldfinch	*Carduelis carduelis*	1.193	0.351	0.245
Welcome Swallow	*Hirundo neoxena*	0.001	0.001	0.001
Silvereye	*Zosterops lateralis*	0.009	0.009	0.009
Common Blackbird	*Turdus merula*	0.018	0.018	0.018
raptor sp.		0.036	0.016	0.014
unidentified passerine		0.459	0.152	0.113
gull sp.		0.044	0.044	0.044
Total annual movements at risk for all birds		**14.920**	**5.259**	**4.051**

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