Macarthur Wind Farm

Bat and Avifauna Mortality Monitoring

March 2013 to February 2014

Prepared for AGL Energy Limited

June 2014

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EXECUTIVE SUMMARY

Following completion of construction and commissioning of the Macarthur Wind Farm in January 2013, the Bat and Avifauna Management Plan for the wind farm was implemented. One of the requirements of this Plan is to undertake a bat and avifauna mortality monitoring program to examine the number and species of birds and bats killed by collision with the blades of turbines and to estimate the number of birds and bats killed per turbine per year and the number killed over the entire wind farm during the monitoring period. This monitoring program commenced in February 2013 in accordance with the endorsed Bat and Avifauna Management Plan and involved monthly carcass searches being undertaken at a sample of 48 turbines, distributed throughout the wind farm. The first month of carcass searches was undertaken to clear carcasses that had previously accumulated in the search areas. All subsequent carcass searches were undertaken by an Ecologist who walked perpendicular transect lines in a plot (230 x 230m) centred around the turbine and searched the ground for bird or bat carcasses, or remains of such.

Searcher efficiency and scavenger trials were undertaken in each season to develop correction factors for calculations of mortality to account for deficiencies in the searcher being able to find all carcasses available and for the removal of carcasses by scavengers prior to the search being conducted each month. This report details the results of bird and bat mortality monitoring from March 2013 to the end of February 2014.

Mortality was estimated separately for small, medium and large birds and all birds combined as well as for bats. Mortality was calculated for each carcass type in each season as well as over all 12 months and was expressed as the mean number of birds and bats killed per turbine per season and year as well as total number of birds and bats killed per season and year.

A total of 65 individual birds from 15 species and six bats from three species were found during carcass searches. An additional 10 birds were found incidentally by maintenance staff and others not involved in scheduled carcass searches. Medium sized birds suffered the highest rates of mortality (5.62 / turbine / year), followed by small birds (4.47 / turbine / year) and large birds (0.10 / turbine / year). All birds averaged 10.19 birds / turbine / year and bat mortality averaged 1.41 / turbine / year. Such estimates of mortality, however, are considered to be inaccurate due to the frequent removal of carcasses by scavengers and therefore high reliance on correction factors for scavenging rates rather than actual mortalities in calculations of mortality over the wind farm. A more frequent carcass search interval is recommended to reduce the reliance on correction factors for scavenging rates and improve the accuracy of future mortality estimates.

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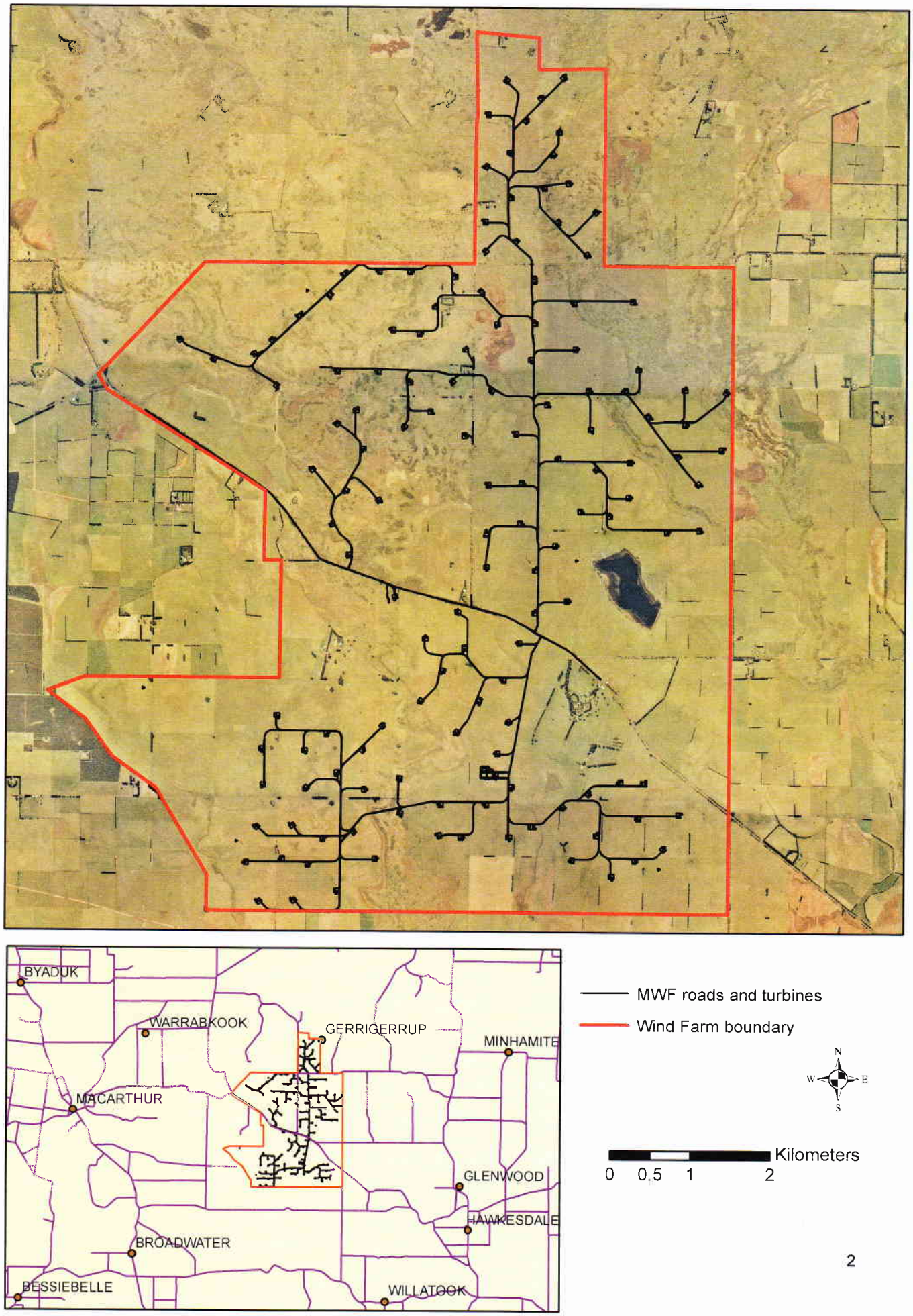
1.0 INTRODUCTION

AGL Energy Limited engaged Vestas Australian Wind Technology Pty Ltd and Leighton Contractors Pty Ltd to build the Macarthur Wind Farm approximately 15km east of Macarthur in south-west Victoria. Construction of the Wind Farm was completed in late 2012 and was commissioned on 31 January 2013. The Macarthur Wind Farm is now jointly owned by AGL Energy Limited and Malakoff Corporation Berhad. The Macarthur Wind Farm is currently the largest wind farm in the southern hemisphere, consisting of 140 turbines with a total capacity of 420 megawatts and is located on approximately 5,500 ha of privately owned agricultural land (Figure 1).

In accordance with the Planning Permit conditions and the endorsed Bat and Avifauna Management Plan of the Macarthur Wind Farm, a monitoring program to assess bird and bat mortality resulting from collision with the blades of wind turbines is required to be undertaken for at least two years following completion of construction and commissioning of the wind farm. This monitoring program commenced in February 2013 and consists of monthly searches for dead birds and bats, or evidence of such, within a plot (230 x 230m) centred around a sample of 48 turbines.

The following report details the results of the first 12 months of bird and bat mortality monitoring at the Macarthur Wind Farm, documenting the bird and bat fatalities recorded to date, and estimates the seasonal and annual mortality of birds and bats attributable to collision with the blades of wind turbines.

Figure 1. Location of the Macarthur Wind Farm



2.0 METHODS

Mortality of birds and bats resulting from collision with the blades of wind turbines were investigated by searching the ground under and around wind turbines for carcasses or other evidence of bird or bat mortality. In combination with correction factors for searcher efficiency and scavenging rates, the number of dead birds and bats found under wind turbines were used to calculate an estimate of seasonal and annual mortality. All mortalities of birds and bats found near wind turbines were assumed to have occurred as a result of collision with blades or from barotrauma, in the case of bats.

2.1 Carcass Searches

A sample of 48 turbines, as stipulated by the Bat and Avifauna Management Plan, were randomly selected using SPSS statistical software to generate a set of random numbers between 1 and 140. The suitability of each turbine was examined in the field to ensure carcass searches would not be impeded by electric fences or inaccessible areas such as wetlands which may be inundated during the winter months. Where a turbine was considered unsuitable for a carcass search, a new turbine number was randomly selected. The locations of turbines used for carcass searches are shown in Figure 2.

Carcass searches were undertaken once per month at each of the 48 selected turbines, attempting as far as possible to maintain the same schedule and time interval between consecutive searches of the same turbine. The mean time interval between consecutive carcass searches at the same turbine was 30.53 ± 0.15 days. When turbine maintenance interfered with the schedule, the next turbine on the list was searched and that which had been missed was searched at the next opportunity. Carcass searches commenced in February 2013 when all 48 turbines were searched primarily to remove any carcasses that had already accumulated. Carcasses found during this initial 'clearing search' were noted but excluded from analyses of seasonal and annual mortality.

Carcass searches consisted of walking along transects within a square plot, each side measuring 230 m (5.29 ha), centred around the turbine. Given that large birds hit by turbine blades can be projected greater distances from a turbine than smaller birds and bats and that the probability of finding larger carcasses is greater than for smaller carcasses (Hull and Muir 2010), carcass search plots were divided into two areas; an inner area of 130 x 130m intensively searched along parallel transects spaced 5 m apart to improve the probability of finding smaller birds and bats, whilst the outer area between 65 and 115 m from the turbine was searched along transects at

15m intervals, primarily to focus on finding large birds. The size of these search plots were determined following recommendations by Hull and Muir (2010) relative to the height of the turbines and length of blades. GIS (ArcMap) was used to create a spatial layer of transect locations within each of the 48 search plots which was then uploaded to a handheld GPS unit (Garmin GPSMap 78S). The GPS was used in the field to navigate along transect lines during carcass searches. An example of the layout of transect lines within a search plot is provided in Figure 3.

Carcass search data sheets were completed for each carcass search, regardless of whether a carcass was found. The data sheet is provided in Appendix 1. When a carcass or remains of a carcass, such as a feather spot or body part, was found the following details were noted: Turbine number, date and time of find, species, distance and bearing from turbine base, type of remains (carcass / feather spot), any signs of injury, degree of decay, any evidence of scavenging, substrate conditions within 1m² of the carcass, distance from observer to carcass when first located, and perpendicular distance from transect line. A photograph was taken of the carcass / feather spot as found before it was placed in a sealed plastic bag and later transferred to a freezer.

Any carcasses found within carcass search areas but not during scheduled carcass searches were noted but left undisturbed so that it was potentially available to be found during the next formal carcass search, providing it was not removed by a scavenger within that time. Any carcasses found by maintenance personnel near turbines that were not searched as part of the carcass search program were photographed, collected and placed in a chest freezer on site. The incidental find was reported to site management using an "Incidental bird or bat carcass find report" form.

To enable a correction factor to be applied to calculations of bird and bat mortality which accounted for deficiencies of searches in detecting carcasses, searcher efficiency trials were undertaken to provide an estimate of the probability of a carcass being found. Similarly, scavenger trials were undertaken to estimate the duration a carcass remains in situ or is still detectable by a searcher before being removed by a scavenger. The combination of these factors were used to develop a correction factor for calculations of mortality which estimate the probability of a carcass being found should it be available (i.e. not removed by a scavenger). Searcher efficiency and scavenger trials were conducted each season during the monitoring period to account for variation in the visibility of carcasses in periods of different vegetation cover and rates of scavenging (AERS 2013a, 2013b, 2013c, 2014).

Figure 2. Distribution of turbines used for carcass searches at the Macarthur Wind Farm

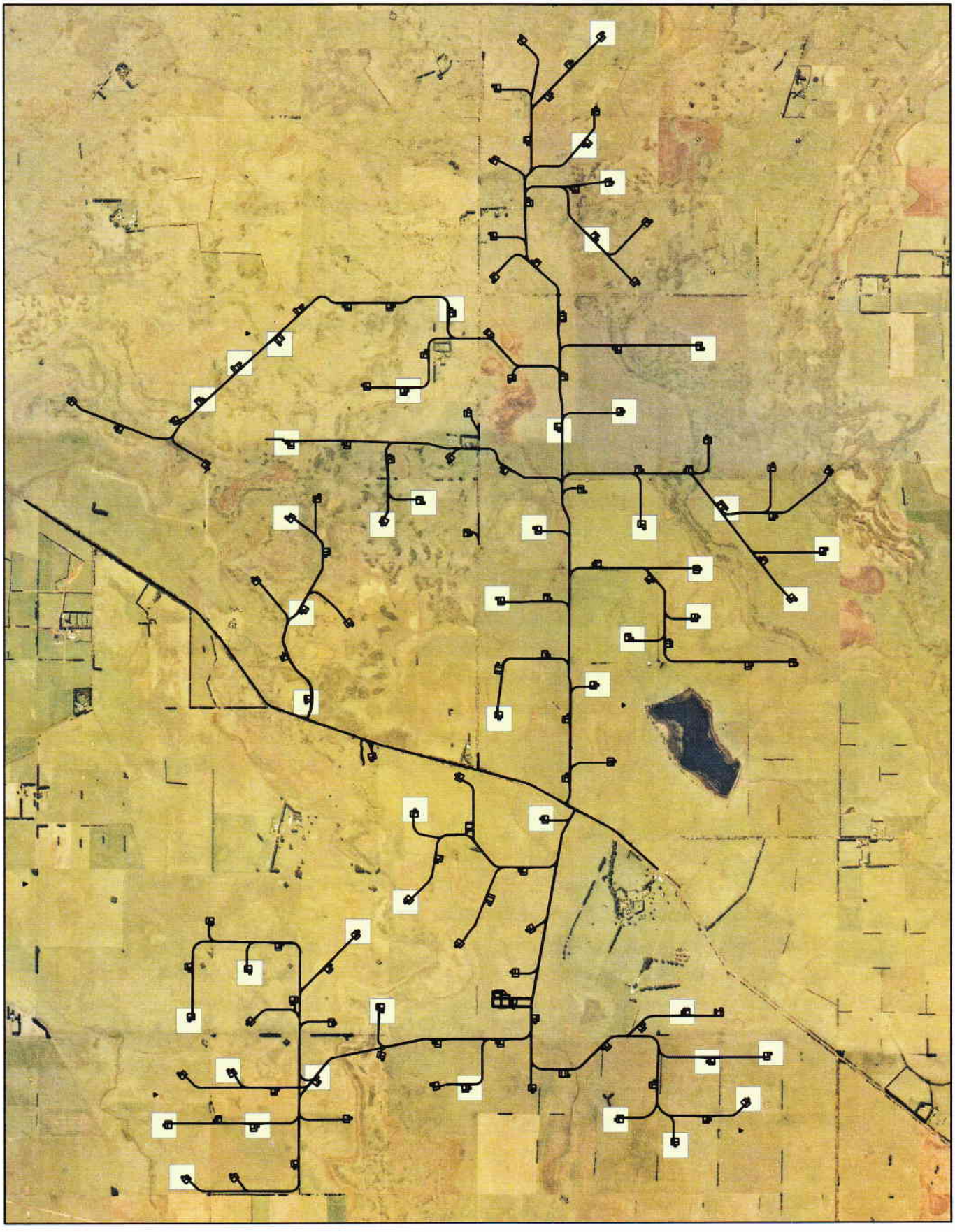
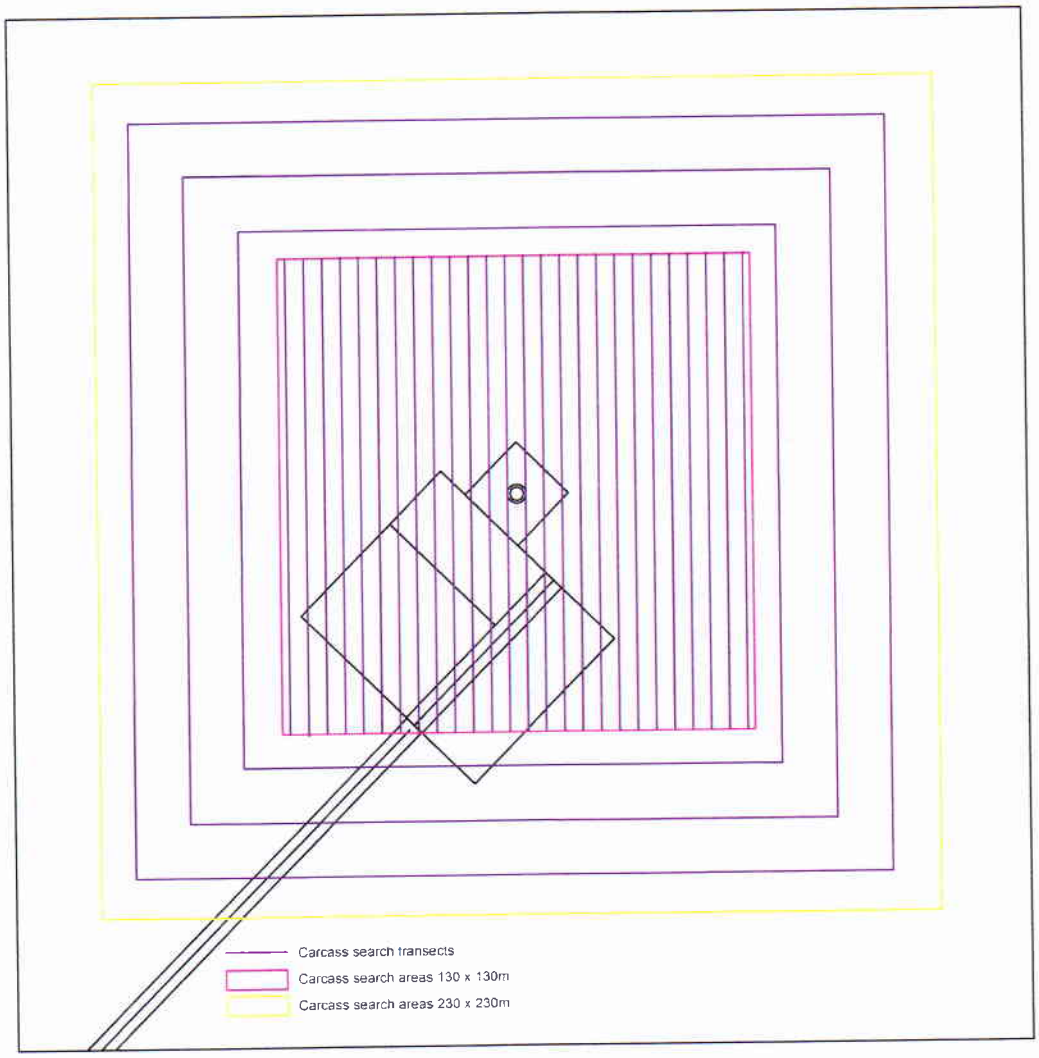


Figure 3. Representation of transect locations within carcass search plots.



2.2 *Searcher Efficiency Trials*

Estimates of searcher efficiency were used to adjust the number of carcasses found during carcass searches in calculations of mortality to account for deficiencies of searchers in detecting carcasses. Searcher efficiency trials were undertaken during the middle of each season at a sample of nine turbines scheduled for carcass searches. Just prior to commencement of the trial, between six and eight carcasses ranging in size and type of bird or bat, collected from road kill or mortalities previously found at the wind farm (collected under Wildlife Act 1975 Research Permit No. 10006657), were randomly placed within the search area of turbines to be searched that day. Where bats were in short supply, brown mice were used as substitutes. Additionally, since Brolga

are known to utilise the wind farm site, particularly throughout their breeding season, an estimate of searcher efficiency in detecting these birds was considered very important to accurately estimate mortality of this species. As Brolga carcasses were not available for use in the trials, Slate Grey Turkeys were used as substitutes. These turkeys closely resembled a Brolga in colouration and size. All carcasses were frozen and thawed on the day of the trial. The location and number of carcasses placed at each turbine was not known by the searcher undertaking the trial.

As bats and small birds are unlikely to fall beyond 65 m from the turbine, based on calculations described by Hull and Muir (2010), these carcasses were only placed within the inner search area of 130 x 130m. Large and medium birds, however, may fall beyond 65 m from the turbine. As such, medium birds were placed within both the inner and outer search areas (230 x 230m), whilst large birds were only placed within the outer search area. It was assumed that all large birds would be found if placed within the inner search area given the more intensive search effort.

After each carcass had been placed within the search plot, the searcher followed the same procedure used for formal carcass searches. At the end of each carcass search, the number and proportion of all carcasses found was recorded. The efficiency of detecting carcasses was estimated separately for large, medium and small birds and bats / mice, and averaged over all nine carcass searches. Additionally, since the inner and outer search areas were searched at different intensities (i.e. respective transect intervals of 5m and 15m), the searcher efficiency of finding medium birds was determined separately for the inner and outer plots.

2.3 Scavenger Trials

Scavenger trials were undertaken to estimate the time a carcass remains in situ before it is removed by a scavenger. The average carcass removal time was used to adjust calculations of mortality for removal bias. Scavenging rates were estimated for different sizes of birds (small, medium and large) and separately for bats. Scavenging rates were also estimated separately for each season to account for seasonal differences in forage availability and visibility of carcasses in varying height and density of vegetation.

Scavenger trials were undertaken over 30 consecutive days during approximately the middle of each season. Each trial consisted of randomly placing 3 to 5 carcasses, ranging in size from small birds and bats to large Turkeys, within 100m of each of 10 turbines. Only turbines that were not used in scheduled carcass searches were selected for the scavenger trials to ensure trial

carcasses were not confused with actual fatalities in subsequent carcass searches. The same 10 turbines were used for scavenger trials in each season.

Carcasses were sourced from either road kill or from fatalities previously found on the wind farm with permission granted under Wildlife Act 1975 Research Permit No. 10006657. Most carcasses were frozen and thawed on the day of the trial. Each carcass was labelled with an identification number using a small sticker around the leg and their locations were marked with a wooden stake and recorded on a GPS.

Given that Brolgas are known to occur on the wind farm site, particularly during their breeding season, it is important to examine the potential rate of scavenging on these birds. As a substitute for Brolgas, Slate-grey Turkeys, which resemble Brolga were purchased fresh from a Turkey Farm in western Victoria. Turkeys were whole feathered and transported via refrigerated courier directly to the wind farm the morning after being euthanised.

All carcasses were checked each day over 30 consecutive days to determine whether they had been scavenged, either completely removed or partially, noting evidence of scavenging, such as movement of carcass, tearing or pecking, and remains of body parts. Where a carcass was removed by a scavenger, notes were recorded as to whether evidence of the carcass still remained such as feather spots or body parts which would most likely be detected during a carcass search. Carcasses or remains of such were checked daily until there was no further remains detectable or until the end of the trial. The scavenger trial data sheet is provided in Appendix 2.

2.4 Data Analyses

Searcher efficiency trials

Searcher efficiency rates are expressed as p, the proportion of trial carcasses that are detected by searchers.

Scavenger trials

Estimates of scavenging rates was used to adjust carcass counts for removal bias. The correction factor was expressed as the mean carcass removal time ($\bar{t}$), which was the average number of days a carcass remains at the site before it is removed. This was calculated following the formula:

$$\bar{t} = \frac{\sum_{i=1}^{s} t_i}{S - S_c}$$, where t_i is the removal time of the ith carcass, s is the number of carcasses used in the trials, and s_c is the number of carcasses remaining at the end of the trial. (Source: Erickson *et al.* 2003). Carcass removal time was defined as the time taken for all evidence of the carcass such as feathers and body parts to be no longer detectable.

A correction factor for scavenging rate was determined separately for large, medium and small birds and mice / bats by the average carcass removal time ($\bar{t}$), for each carcass type.

Estimation of mortality

An estimate mortality (m_1) for birds (small, medium and large) and bats at each turbine was calculated as follows:

$$m_1 = \frac{c}{\pi_1}$$,

where c = the number of carcasses found in carcass searches,

$\pi_1 = \frac{\bar{t}.p}{I}$ where p is the estimated searcher efficiency rate, $\bar{t}$ is the estimated carcass removal time, and I is the average interval (in days) between consecutive carcass searches (Source: Erickson *et al.* 2003). Different searcher efficiency and scavenging rates were used according to the season in which the carcass search was undertaken. Where the average carcass removal time determined by the scavenger trials exceeded the search interval between consecutive carcass searches, the average removal time was adjusted to the same time as the search interval.

Mortality was estimated per turbine per month as well as per turbine per season and per turbine per year. The mean seasonal and annual mortality was calculated from monthly estimates in each season and from all months combined. Total annual mortality at each turbine was calculated by summing monthly mortality estimates for all birds and bats and separately for large, medium and small birds.

3.0 RESULTS

3.1 Carcass Searchers

Searches at the 48 selected turbines commenced in February 2013. Searches during this first month were undertaken solely to remove any carcasses that had previously accumulated. 12 carcasses were removed; four White-striped Freetail Bats, three Gould's Wattled Bats, two Australian Magpies, one Nankeen Kestrel, feathers and skeletal remains of a Wedge-tail Eagle and a feather spot of an unknown bird of prey. These data were not included in mortality estimates. A total of 576 carcass searches (12 searches of 48 turbines) were conducted over the subsequent 12 months from March 2013 to February 2014.

3 raptors

Bird fatalities

A total of 65 bird fatalities were found during carcass searches from March 2013 to February 2014 consisting of 55 feather spots and 10 carcasses. Bird fatalities consisted of 15 species and an additional 15 unidentified birds found only as feather spots (Table 1). The Australian Magpie was the most common fatality found (15.4% of fatalities). Bird fatalities included feather spots from two Guinea Fowl which are believed to have been killed by Foxes rather than from collision with turbine blades. However, they are included in estimates of mortality as the cause of death could not be definitively determined. Carcasses of two threatened bird species were found; the Black Falcon, listed as vulnerable under the Advisory List of Threatened Vertebrate Fauna in Victoria (DSE 2013) and the Fork-tailed Swift, a listed Migratory species under the EPBC Act 1999.

15 unidentified

An additional 10 bird carcasses were found incidentally near turbines by maintenance personnel, landowners or ecologists when not undertaking scheduled carcass searches. These carcasses included four Wedge-tail Eagles, two Nankeen Kestrels, two Magpies and two Brown Falcons. These carcasses were excluded from estimates of mortality.

8 raptors

Bat fatalities

A total of six bat carcasses from three species were found during carcass searches from March 2013 to February 2014 (Table 1). The White-striped Freetail Bat was the most common bat fatality found (50% of fatalities). An additional carcass of a White-striped Freetail Bat was found incidentally near a turbine. This carcass was excluded from estimates of mortality.

Searches far too infrequent if only 1 in 7 are found as whole carcases many more have been eaten or carried off

Table 1. Summary of bird and bat fatalities found during carcass searches

Common name	Scientific name	Total
Australian Magpie	*Cracticus tibicen*	10
Magpie Lark	*Grallina cyanoleuca*	7
Brown Falcon	*Falco beringora*	6
Nankeen Kestrel	*Falco cenchroides*	5
Eurasian Skylark	*Alauda arvensis*	5
Raven sp.	*Corvus sp.*	4
Wedge-tail Eagle	*Aquila audax*	2
Corella sp.	*Cacatua tenuirostris*	2
Guinea Fowl	*Numida meleagris*	2
Black Falcon	*Falco subniger*	1
Black-shouldered Kite	*Elanus axillaris*	2
Spotted Harrier	*Circus assimilis*	1
Fork-tailed Swift	*Apus pacificus*	1
European Goldfinch	*Carduelis carduelis*	1
Duck sp.		1
Unknown species		15
Avian Sub-total		**65**
White-striped Freetail Bat	*Tadarida australis*	3
Gould's Wattled Bat	*Chalinolobus gouldii*	2
Lesser Long-eared Bat	*Nyctophilus geoffroyi*	1
Bat Sub-total		**6**

17 raptors

plus 3 raptors day 1
plus 8 raptors found by
motorcar between Surv

multiply by 3.5 to cover all undSurv ⇒ 98 + 52 unknown ⇒ 28 minimum -
Bodies Removed

3.2 Searcher Efficiency Trials

Searcher efficiency trials were conducted at nine turbines in each season. The results of searcher efficiency trials are provided separately for each season in Tables 2 - 5.. The type and number of each carcass used at each turbine and whether the carcass was found during the searcher efficiency trials are detailed separately for each season in Appendices 3 - 6.

Autumn 2013

Table 2. Searcher efficiency for each carcass type and search area – Autumn 2013

Carcass type	Search area	Number of carcasses available	Number found	Searcher efficiency (%)
Large bird	Outer	10	10	100
Medium bird	Inner	12	12	100
	Outer	8	8	100
Small bird	Inner	13	8	61.5
Bat	Inner	14	7	50

Winter 2013

Table 3. Searcher efficiency for each carcass type and search area – Winter 2013

Carcass type	Search area	Number of carcasses available	Number found	Searcher efficiency (%)
Large bird	Outer	9	9	100
Medium bird	Inner	12	12	100
	Outer	14	13	93
Small bird	Inner	15	6	40
Mouse	Inner	18	8	44

Spring 2013

Table 4. Searcher efficiency for each carcass type and search area – Spring 2013

Carcass type	Search area	Number of carcasses available	Number found	Searcher efficiency (%)
Large bird	Outer	9	9	100
Medium bird	Inner	12	12	100
	Outer	11	10	90.9
Small bird	Inner	9	6	66.7
Bat / Mouse	Inner	19	3	15.8

Summer 2014

Table 5. Searcher efficiency for each carcass type and search area – Summer 2014

Carcass type	Search area	Number of carcasses available	Number found	Searcher efficiency (%)
Large bird	Outer	9	9	100
Medium bird	Inner	16	15	93.8
	Outer	9	6	66.7
Small bird	Inner	16	10	62.5
Bat	Inner	12	7	58.3

3.3 Scavenger Trials

Scavenger trials were conducted at 10 turbines in each season. The average carcass duration for large, medium and small birds and bats is calculated separately for each season. Carcass duration is defined as the average time for a carcass to be removed and no longer detectable. Further details are provided in separate reports (Wood 2013a, 2013b, 2013c, 2014a).

The rate at which carcasses were removed and were no longer detectable for each carcass type in each season is shown in Figures 4 - 7. The average carcass duration for each carcass type in each season is detailed in Tables 6 - 9.

Figure 4. Scavenging rates of carcass types – Autumn 2013

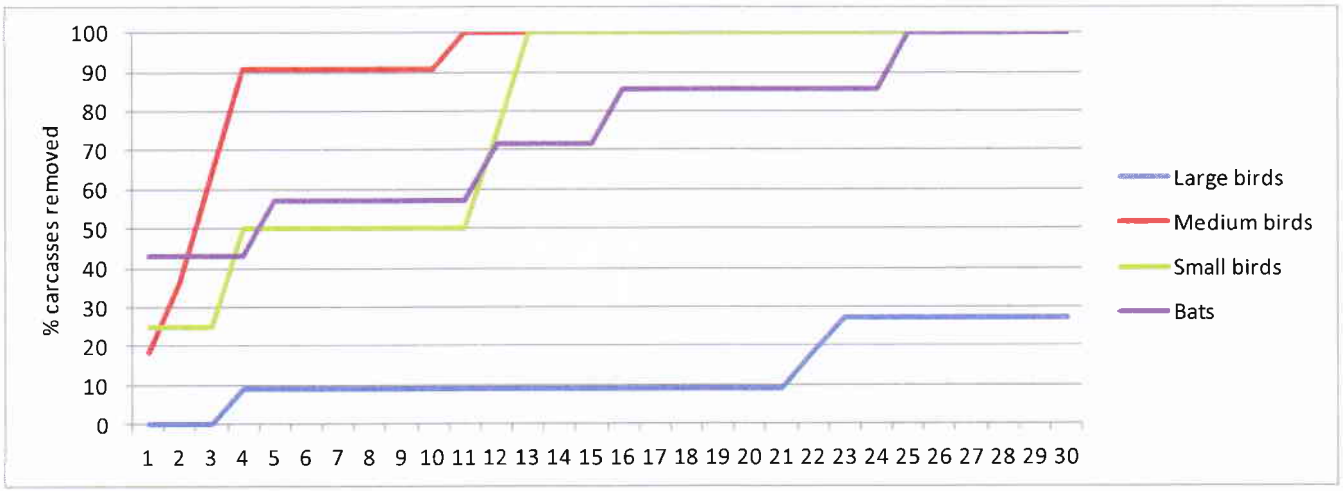


Table 6. Average duration of carcass types in Autumn 2013.

Carcass type	Average duration (days)
Large bird (n = 11)	96.33
Medium bird (n = 11)	3.45
Small bird (n = 4)	7.50
Bat (n = 7)	8.71

Figure 5. Scavenging rates of carcass types – Winter 2013

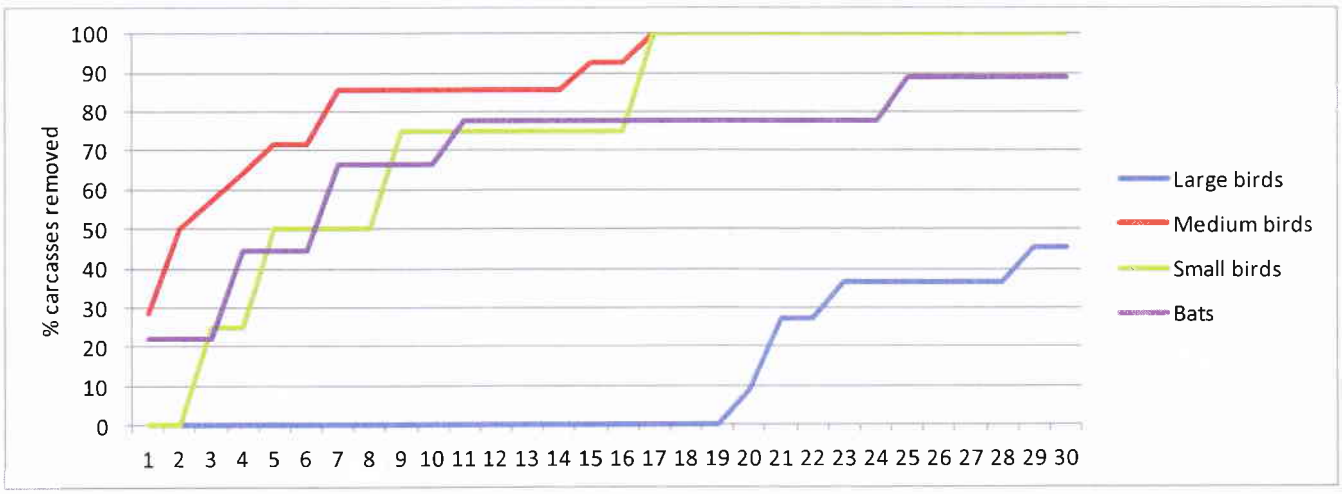


Table 7. Average duration of carcass types in Winter 2013.

Carcass type	Average duration (days)
Large bird (n = 11)	58.80
Medium bird (n = 14)	4.86
Small bird (n = 4)	8.50
Bat (n = 9)	11.25

Figure 6. Scavenging rates of carcass types – Spring 2013

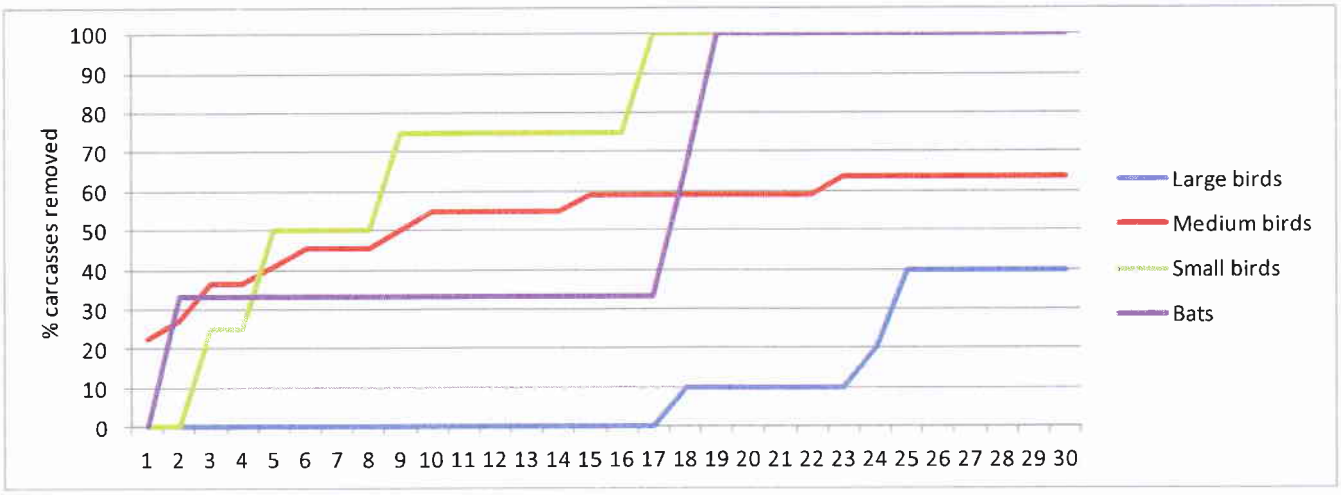
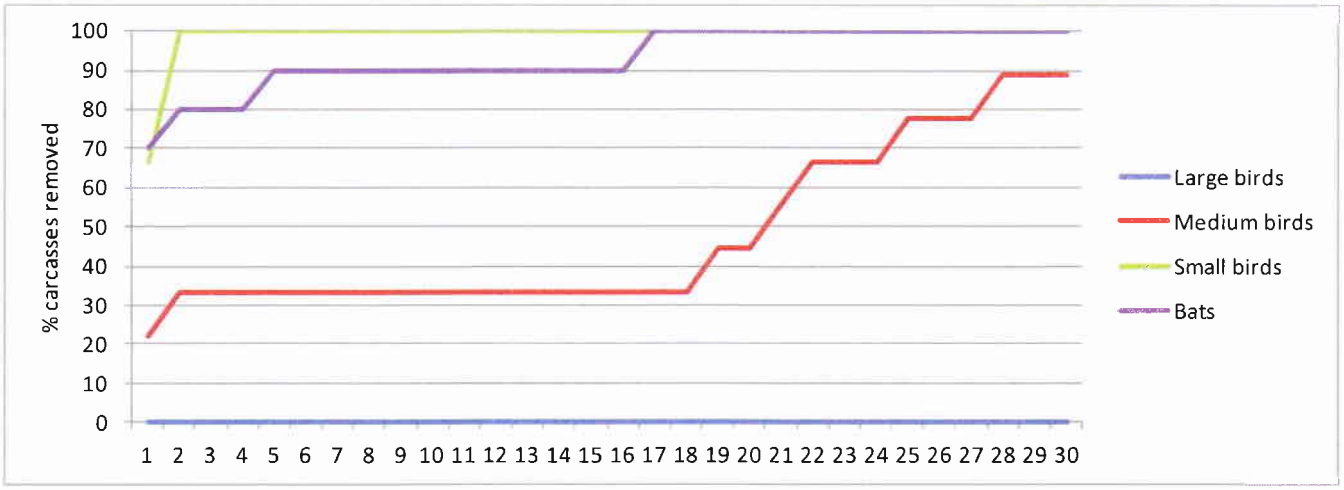


Table 8. Average duration of carcass types in Spring 2013.

Carcass type	Average duration (days)
Large bird (n = 10)	68.00
Medium bird (n = 22)	22.90
Small bird (n = 1)	5.00
Bat (n = 3)	13.00

Figure 7. Scavenging rates of carcass types – Summer 2014



Since all Turkey carcasses were still detectable at the end of the summer scavenger trial even though all carcasses had been removed, it was not possible to calculate an average carcass duration for large birds.

Table 9. Average duration of carcass types in Summer 2014.

Carcass type	Average duration (days)
Large bird (n = 10)	N/A
Medium bird (n = 9)	18.6
Small bird (n = 3)	1.3
Bat (n = 10)	3.1

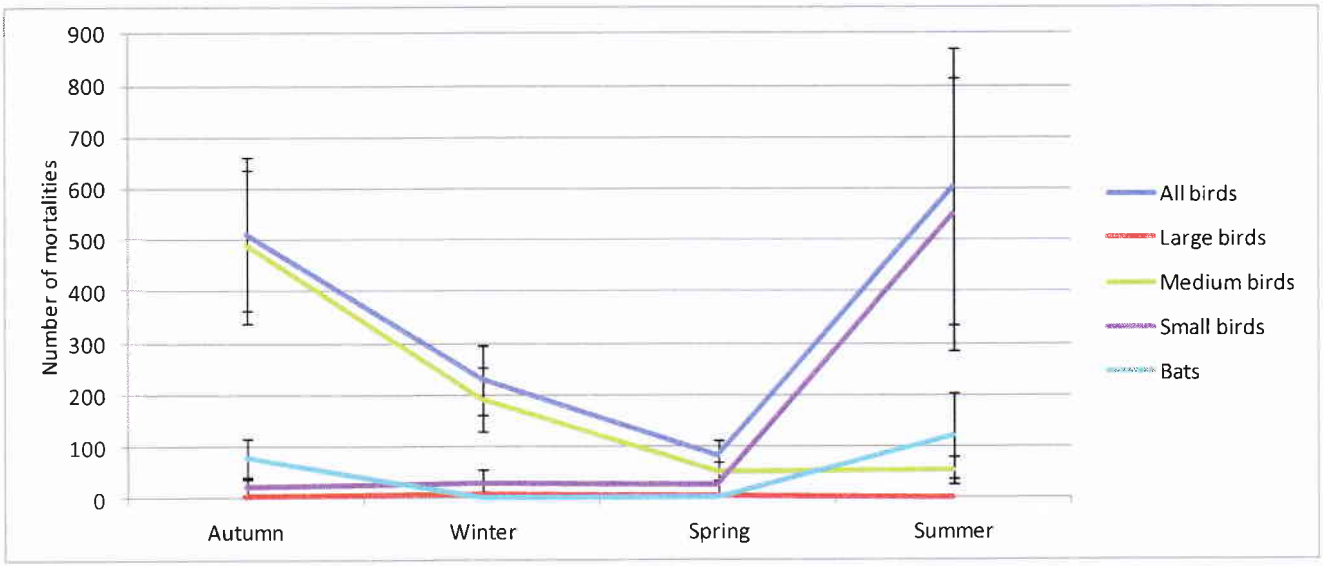
3.4 Estimates of Mortality

3.4.1 Seasonal Mortality

There was no significant difference between seasons in overall bird mortality at the wind farm ($F = 2.382$, d.f. = 3, $p = 0.071$), although mortality tended to be greatest in summer and lowest in spring (Figure 9). Bird mortality, however, varied significantly depending on the size of bird ($F = 5.014$, d.f. = 2, $p = 0.007$) and seasonal mortality differed between bird sizes ($F = 5.515$, d.f. = 6, $p < 0.001$). Over all seasons, mortality was greatest for birds of medium size, followed by small birds and lowest for large birds. However, mortality of medium birds was greatest in autumn whilst that of small birds was greatest in summer with relatively low mortality in the other seasons. Mortality of large birds was relatively low in all seasons with most fatalities occurring in winter (Figure 8). Table 10 details the mean number of birds of each size class estimated to have been killed per turbine and total number killed in each season.

Bat mortalities were only found in autumn and summer. There was no significant difference between these seasons in the estimated number of bat mortalities, although the highest mortalities were estimated to occur in summer (Figure 8). Estimated mortality of bats in terms of the mean number killed per turbine and total number killed over the wind farm in each season is detailed in Table 10.

Figure 8. Estimated seasonal mortality of birds and bats



Error bars represent standard errors.

Table 10. Estimates of seasonal and annual bird and bat mortality

Season	Group	No. of fatalities found	Mean No. Of fatalities per turbine	95% Confidence Interval		Total mortality estimate (all turbines)	95% Confidence Interval	
				Lower limit	Upper limit		Lower limit	Upper limit
Autumn	Small birds	1	0.15	0	0.45	20.85	0	63.00
	Medium birds	21	3.49	1.36	5.62	488.75	190.40	786.80
	Large birds	1	0.02	0	0.06	2.80	0	8.82
	All birds	23	3.66	1.52	5.80	512.52	212.80	812.00
	Bats	4	0.55	0.01	1.09	77.03	1.40	152.60
Winter	Small birds	1	0.02	0	0.61	28.32	0	85.40
	Medium birds	10	1.38	0.49	2.26	192.91	68.60	316.40
	Large birds	3	0.06	0	0.13	8.75	0	18.20
	All birds	14	1.64	0.68	2.61	229.98	95.20	365.40
	Bats	0	0	0	0	0	0	0
Spring	Small birds	1	0.19	0	0.58	26.60	0	81.20
	Medium birds	12	0.37	0.13	0.60	51.80	18.20	84.00
	Large birds	1	0.02	0	0.06	2.80	0	8.82
	All birds	14	0.58	0.14	1.02	81.20	19.60	142.80
	Bats	0	0	0	0	0	0	0
Summer	Small birds	4	3.92	0.10	7.74	548.80	14.00	1083.60
	Medium birds	9	0.39	0.02	0.75	54.60	2.80	105.00
	Large birds	0	0	0	0	0	0	0
	All birds	13	4.31	0.47	8.15	603.40	65.80	1141.00
	Bats	2	0.87	0	2.08	121.80	0	291.20
All seasons (12 months)	Small birds	7	4.47	0.65	8.29	625.80	91.00	1160.60
	Medium birds	52	5.62	3.05	8.19	786.80	427.00	1146.60
	Large birds	5	0.10	0	0.21	14.00	0	29.40
	All birds	64	10.19	4.95	15.44	1426.60	693.00	2161.60
	Bats	6	1.42	0.12	2.71	198.80	16.80	379.40

The estimates of mortality for each bird size and bats at each turbine in each season and over all seasons are shown in Appendices 7 – 11.

3.4.2 Annual Mortality

The mean number of birds killed per turbine from March 2013 to end of February 2014 was estimated to be 10.19 ± 2.61. Medium sized birds suffered the highest mortality of 5.62 ± 1.28 birds per turbine per year. The mortality of small birds was estimated at 4.47 ± 1.89 birds per turbine per year and that of large birds was relatively low, averaging 0.10 ± 0.05 per turbine per year, (Table 10). Bat mortality was estimated at 1.42 ± 0.65 bats per turbine per year (Table 10).

3.5 Spatial distribution of bird and bat fatalities

Bird fatalities were found at 31 of the 48 turbines searched during scheduled carcass searches. Incidental finds of bird carcasses were found at an additional eight turbines not included in the carcass search program. Bat fatalities were found at six of the 48 turbines searched over the 12 months.

Bird fatalities ranged from zero to eight fatalities at any one turbine. The highest number of bird fatalities was recorded at turbine 104. Five fatalities were recorded at turbines 75 and 82, four fatalities were found at turbines 32 and 93 and three fatalities were recorded at turbines 69 and 72. Fatalities at the remaining 32 turbines where fatalities were found consisted of either single or double fatalities over the 12 month period. Single bat fatalities were found at six of the 48 turbines used for carcass searches. No bats have so far been found incidentally.

Figures 9 and 10 respectively show the spatial distribution of all bird and bat fatalities, including those found incidentally, over the 12 months from March 2013 to end of February 2014. Bird fatalities were distributed over the entire wind farm but multiple fatalities at single turbines typically occurred in the central area of the wind farm, with the exception of Turbine number 104 in the south-east of the wind farm where eight bird fatalities were found (Figure 9). There does not appear to be any pattern in the spatial distribution of bat fatalities (Figure 10).

Figure 9. Spatial distribution of bird fatalities at Macarthur Wind Farm

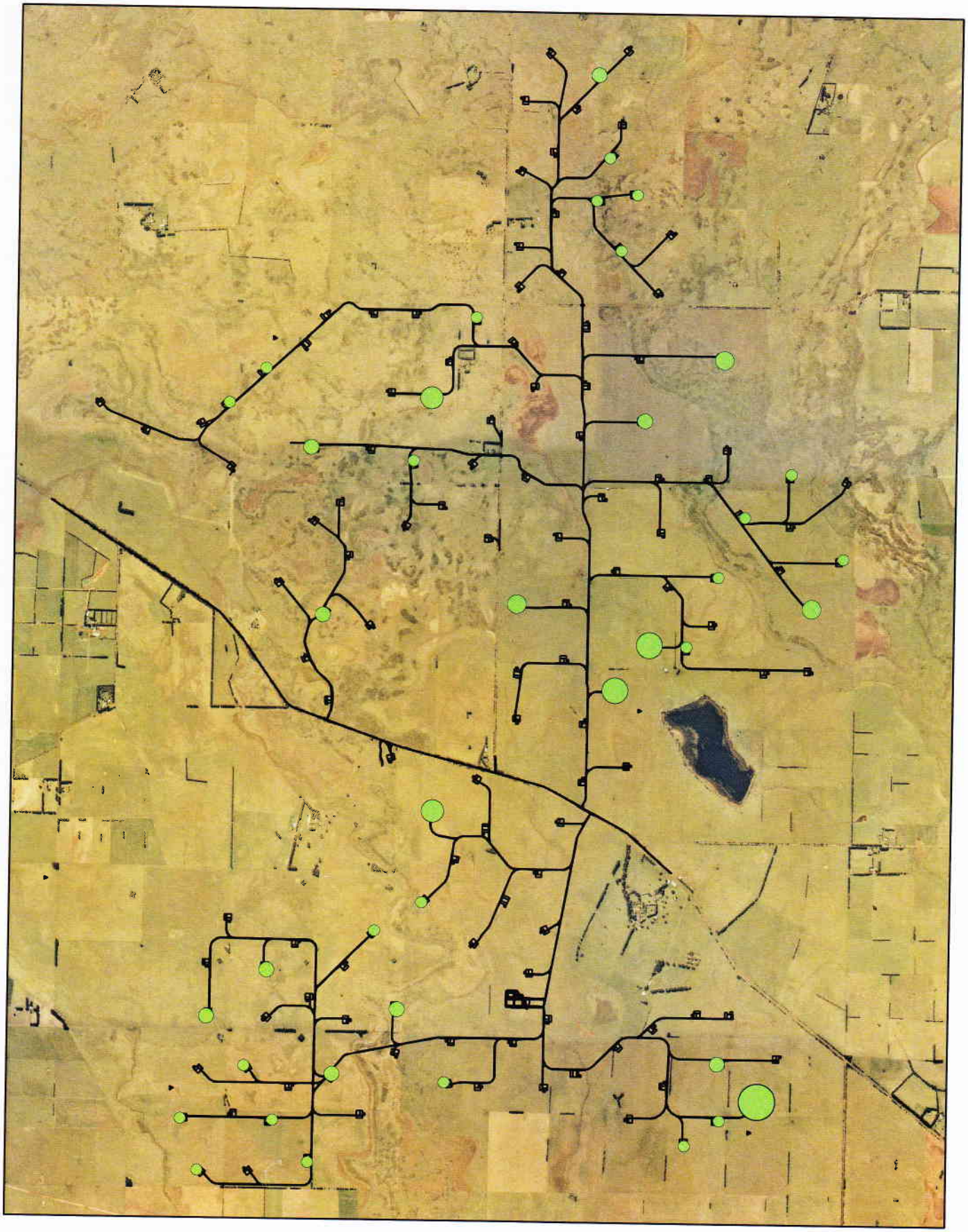
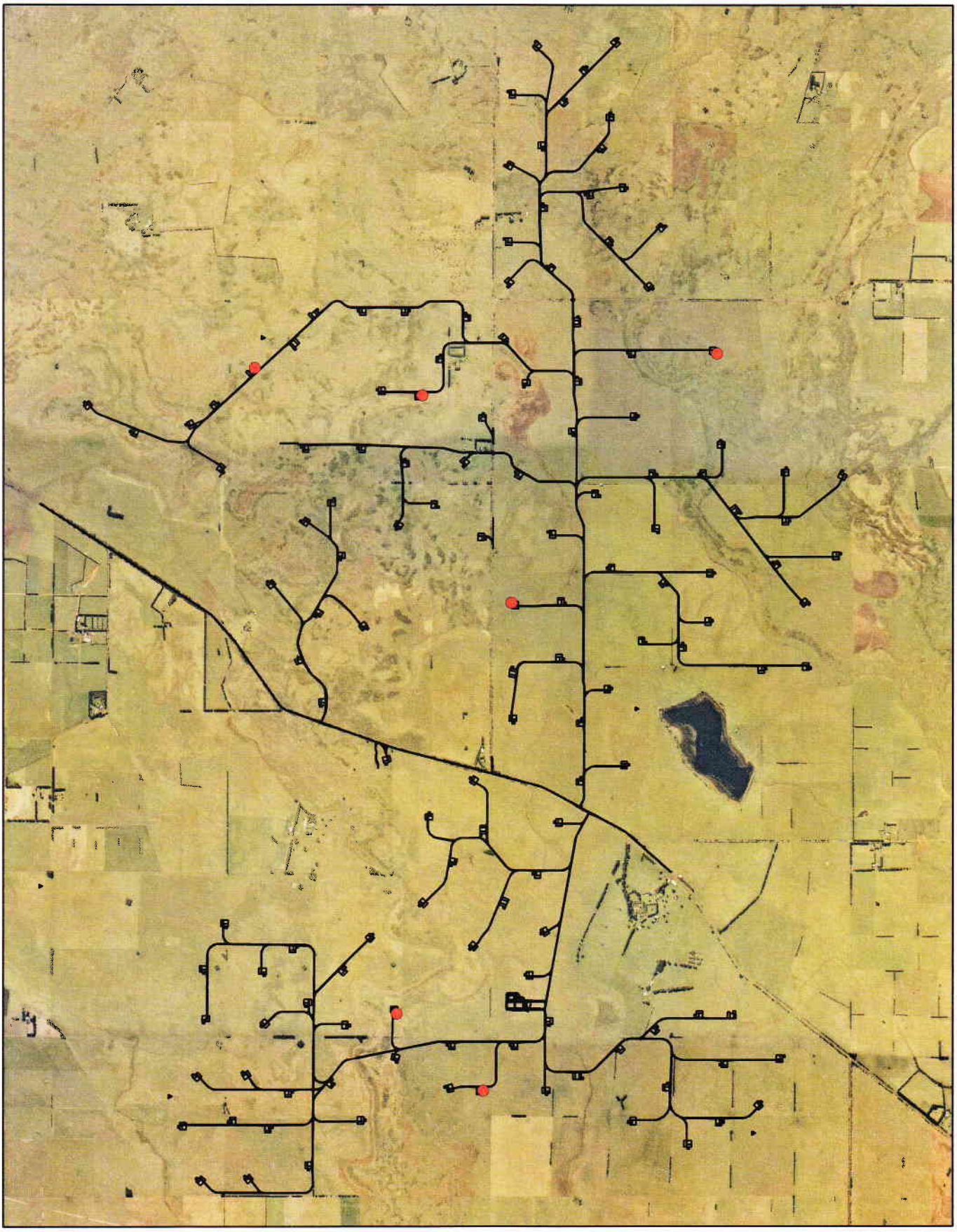


Figure 10. Spatial distribution of bat fatalities at Macarthur Wind Farm



Permit approval on assumption 2/year

4.0 DISCUSSION

Some turbines killing nearly 100 annually

Annual mortality of birds at the Macarthur Wind Farm was estimated at 10.19 ± 2.61 birds per turbine. Medium and small birds were killed more frequently than large birds, respectively averaging of 5.62 ± 1.28, 4.47 ± 1.89 and 0.10 ± 0.05 birds per turbine per year. Most medium sizes birds were killed in autumn whilst small birds were more frequently killed in summer. Mortality of large birds was low in all seasons.

Annual bat mortality averaged 1.42 ± 0.65 bats per turbine per year. Bat mortality only occurred in autumn and summer. It is likely that bats will have also been killed during spring, although none were found. The risk of bat mortality during winter, however, will be significantly reduced as most bats will hibernate over the colder months.

Of the 75 bird fatalities found either during scheduled carcass searches or incidentally by maintenance staff, carcasses of two threatened bird species were found; the Black Falcon, listed as vulnerable under the Advisory List of Threatened Vertebrate Fauna in Victoria (DSE 2013) and the Fork-tailed Swift, a listed Migratory species under the Commonwealth EPBC Act 1999. The Department of Environment and Primary Industries was notified of these mortalities immediately. No fatalities of threatened bat species have so far been found, even though the Critically Endangered Southern Bent-wing Bat has been detected on site and at altitudes within the rotor swept area (Wood, 2014b).

A concurrent survey of bird utilisation at the Macarthur Wind Farm found that the relative abundance of raptors such as Wedgetail Eagles, Spotted Harriers, Brown Falcons, and Nankeen Kestrels on the wind farm site was very low, each species representing < 1% of all birds observed (Wood and Hughes 2014). However, raptors represented approximately 30% of bird fatalities over the 12 months from March 2013 to February 2014. It appears these birds may be at higher risk of collision with the blades of turbines possibly due to a combination of factors such as the altitude they mostly fly at, the proportion of time spent flying and flying behaviour. Raptors tend to glide slowly and are constantly looking downward for potential prey, rather than flying in a single direction and looking where they are heading. This may increase their risk of flying through the rotor swept area of turbines. Other studies have also suggested that raptors are more likely to collide with turbine blades than many other avian species due to their morphology and foraging behaviour (e.g. focus on distant prey), (Barrios & Rodriguez 2004, Hoover & Morrison 2005, Percival 2005, Stewart *et.al.* 2007, Kikuchi 2008, Smallwood *et.al.* 2009, Garvin *et.al.* 2011).

Estimates of bird and bat mortality are subject to several sources of bias which may result in inaccurate estimates. Such sources of bias include the use of correction factors for searcher efficiency and scavenging rates which are ineffective if no fatalities are found at a turbine due to prior removal from scavengers. However, the likeliest source of error in the current estimates of mortality at the Macarthur Wind Farm is the search interval between consecutive carcass searches. Each turbine was searched approximately 30 days apart but as illustrated by the scavenger trials, most carcasses are removed by scavengers within one week. This results in fewer carcasses being detected and of those that are detected, a very high scavenging correction factor is applied. As such, the estimate of mortality is likely to be inaccurate as it relies primarily on correction factors rather than actual fatalities.

It is recommended to increase the frequency of carcass searches to weekly. This would reduce the reliance on correction factors for scavenging rates and therefore provide a much more accurate estimate of mortality over the wind farm. It may be necessary to reduce the number of turbines searched due to limited resources but the benefits obtained by the increased accuracy of carcass searches at individual turbines would outweigh the reduced sample size.

5.0 REFERENCES

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6.0 APPENDICES

Appendix 1. Carcass search data sheet

Macarthur Wind Farm - Bat and Avifauna Mortality Monitoring Program

Carcass Search Data Sheet

Observer: Date:
Turbine number: Start time: Finish time:

Visibility (High / Low) based on vegetation structure, rock cover etc.:
Agricultural activities (e.g. presence of cattle, sheep, cropping):

If carcass, feather spot or injured bird or bat is found complete the following:

	Carcass 1	Carcass 2	Carcass 3
Time of find:			
Distance from turbine base (m):			
Direction from turbine base (deg):			
Coordinates AGD66			
Species (if known):			
Type of remains (carcass / featherspot):			
Signs of injury:			
Photo taken (yes / no):			
Degree of decay:			
Evidence of scavenging or movement:			
Substrate conditions within 1m² of carcass location (height and density of vegetation, presence of stock etc):			
Distance from observer to carcass when first located:			
Perpendicular distance to transect line:			

Appendix 2. Macarthur Wind Farm - Scavenger trial data sheet.

Turbine ID number:			Date of initial carcass placement:	
Number of carcasses placed at site:	Large birds		Medium birds	
	Small birds		Bats	

Date of observation:

Carcass species:	Carcass ID No.	Carcass type: (large bird, medium bird, small bird, bat)	Condition at placement (fresh, frozen, state of decay)	Substrate conditions within 1m² of placement (high / low vegetation, bare ground, rocks etc)	Scavenged (Yes / No)	If scavenged, was there complete or partial removal?	Partial removal:		
							Note animal parts remaining (bone, feathers)	Scavenging observations? (tearing, pecking)	Type of scavenger (mammalian or avian)

Appendix 3. Results of searcher efficiency trial – Autumn 2013

Turbine #	Carcass	Carcass type	Search area	Found (Yes / No)
125	Turkey	Large bird	Outer	Yes
	Kookaburra	Medium bird	Inner	Yes
	White-striped Freetail Bat	Bat	Inner	No
	Blue-winged Parrot	Small bird	Inner	Yes
	White-striped Freetail Bat	Bat	Inner	Yes
116	Turkey	Large bird	Outer	Yes
	Gould's Wattled Bat	Bat	Inner	No
	White-striped Freetail Bat	Bat	Inner	Yes
	Sparrow	Small bird	Inner	No
	Magpie	Medium bird	Outer	Yes
104	Wren	Small bird	Inner	Yes
	Eastern Rosella	Medium bird	Outer	Yes
	Magpie	Medium bird	Inner	Yes
	Turkey	Large bird	Outer	Yes
	Eastern Rosella	Medium bird	Inner	Yes
	Raven	Medium bird	Inner	Yes
	White-striped Freetail Bat	Bat	Inner	No
73	Sparrow	Small bird	Inner	No
	Kookaburra	Medium bird	Outer	Yes
	Blue-winged Parrot	Small bird	Inner	Yes
	Magpie	Medium bird	Inner	Yes
	White-striped Freetail Bat	Bat	Inner	No
	White-striped Freetail Bat	Bat	Inner	No
	Turkey	Large bird	Outer	Yes
70	Wren	Small bird	Inner	Yes
	Gould's Wattled Bat	Bat	Inner	No
	White-striped Freetail Bat	Bat	Inner	Yes
	Eastern Rosella	Medium bird	Inner	Yes
	Magpie	Medium bird	Inner	Yes
	Raven	Medium bird	Outer	Yes
	Turkey	Large bird	Outer	Yes
25	Kookaburra	Medium bird	Outer	Yes
	Magpie	Medium bird	Inner	Yes
	White-striped Freetail Bat	Bat	Inner	Yes
	Blue-winged Parrot	Small bird	Inner	Yes
	Sparrow	Small bird	Inner	No
	White-striped Freetail Bat	Bat	Inner	Yes
	Eastern Rosella	Medium bird	Inner	Yes
	Turkey	Large bird	Outer	Yes
56	Raven	Medium bird	Outer	Yes
	Kookaburra	Medium bird	Inner	Yes
	White-striped Freetail Bat	Bat	Inner	No
	White-striped Freetail Bat	Bat	Inner	Yes
	Sparrow	Small bird	Inner	Yes
	Blue-winged Parrot	Small bird	Inner	No
	Turkey	Large bird	Outer	Yes

Turbine #	Carcass	Carcass type	Search area	Found (Yes / No)
34	Turkey	Large bird	Outer	Yes
	Wren	Small bird	Inner	No
	White-striped Freetail Bat	Bat	Inner	Yes
	Magpie	Medium bird	Outer	Yes
	Magpie	Medium bird	Inner	Yes
7	Wren	Small bird	Inner	Yes
	Raven	Medium bird	Outer	Yes
	Blue-winged Parrot	Small bird	Inner	Yes
	Kookaburra	Medium bird	Inner	Yes
	Turkey	Large bird	Outer	Yes

Appendix 4. Results of searcher efficiency trial – Winter 2013

Turbine #	Carcass	Carcass type	Search area	Found (Yes / No)
140	Turkey	Large bird	Outer	Yes
	Mouse	Mouse	Inner	No
	Red-browed Finch	Small bird	Inner	Yes
	Eastern Rosella	Medium bird	Outer	Yes
	Red-browed Finch	Small bird	Inner	No
	Mouse	Mouse	Inner	No
	Magpie	Medium bird	Outer	Yes
	Mouse	Mouse	Inner	No
139	Turkey	Large bird	Outer	Yes
	Eastern Rosella	Medium bird	Inner	Yes
	Eastern Rosella	Medium bird	Outer	No
	Mouse	Mouse	Inner	Yes
	Red-browed Finch	Small bird	Inner	No
	Mouse	Mouse	Inner	No
	Magpie	Medium bird	Inner	Yes
	Red-browed Finch	Small bird	Inner	No
135	Turkey	Large bird	Outer	Yes
	Mouse	Mouse	Inner	Yes
	Eastern Rosella	Medium bird	Inner	Yes
	Mouse	Mouse	Inner	No
	Mouse	Mouse	Inner	No
	Eastern Rosella	Medium bird	Inner	Yes
	Magpie	Medium bird	Outer	Yes
	Red-browed Finch	Small bird	Inner	Yes
	Red-browed Finch	Small bird	Inner	No
10	Turkey	Large bird	Outer	Yes
	Eastern Rosella	Medium bird	Inner	Yes
	Magpie	Medium bird	Outer	Yes
	Red-browed Finch	Small bird	Inner	Yes
	Mouse	Mouse	Inner	Yes
	Mouse	Mouse	Inner	No
	Red-browed Finch	Small bird	Inner	No
	Eastern Rosella	Medium bird	Outer	Yes
75	Turkey	Large bird	Outer	Yes
	Eastern Rosella	Medium bird	Inner	Yes
	Mouse	Mouse	Inner	Yes
	Eastern Rosella	Medium bird	Outer	Yes
	Magpie	Medium bird	Inner	Yes
	Mouse	Mouse	Inner	Yes
	Red-browed Finch	Small bird	Inner	No
64	Turkey	Large bird	Outer	Yes
	Eastern Rosella	Medium bird	Outer	Yes
	Mouse	Mouse	Inner	Yes
	Red-browed Finch	Small bird	Inner	No
	Magpie	Medium bird	Inner	Yes
	Eastern Rosella	Medium bird	Outer	Yes
	Mouse	Mouse	Inner	No

Turbine #	Carcass	Carcass type	Search area	Found (Yes / No)
59	Turkey	Large bird	Outer	Yes
	Magpie	Medium bird	Inner	Yes
	Eastern Rosella	Medium bird	Outer	Yes
	Mouse	Mouse	Inner	Yes
	Red-browed Finch	Small bird	Inner	No
	Mouse	Mouse	Inner	No
	Eastern Rosella	Medium bird	Outer	Yes
93	Turkey	Large bird	Outer	Yes
	Red-browed Finch	Small bird	Inner	Yes
	Magpie	Medium bird	Inner	Yes
	Eastern Rosella	Medium bird	Inner	Yes
	Eastern Rosella	Medium bird	Outer	Yes
	Mouse	Mouse	Inner	No
	Blue-wing Parrot	Small bird	Inner	Yes
111	Turkey	Large bird	Outer	Yes
	Magpie	Medium bird	Outer	Yes
	Blue-wing Parrot	Small bird	Inner	Yes
	Mouse	Mouse	Inner	Yes
	Eastern Rosella	Medium bird	Inner	Yes
	Red-browed Finch	Small bird	Inner	No
	Eastern Rosella	Medium bird	Outer	Yes

Appendix 5. Results of searcher efficiency trial – Spring 2013

Turbine #	Carcass	Carcass type	Search area	Found (Yes / No)
72	Turkey	Large bird	Outer	Yes
	Mouse	Mouse	Inner	No
	Nankeen Kestrel	Medium bird	Inner	Yes
	Magpie	Medium bird	Outer	Yes
	Mouse	Mouse	Inner	No
	Blue wing Parrot	Small bird	Inner	Yes
58	Turkey	Large bird	Outer	Yes
	White-striped Freetail Bat	Bat	Inner	No
	Galah	Medium bird	Outer	Yes
	Mouse	Mouse	Inner	No
	Magpie	Medium bird	Inner	Yes
	Blue wing Parrot	Small bird	Inner	Yes
61	Turkey	Large bird	Outer	Yes
	Magpie	Medium bird	Inner	Yes
	Nankeen Kestrel	Medium bird	Outer	Yes
	Mouse	Mouse	Inner	No
	Mouse	Mouse	Inner	Yes
	Blue wing Parrot	Small bird	Inner	Yes
86	Turkey	Large bird	Outer	Yes
	Magpie	Medium bird	Inner	Yes
	Mouse	Mouse	Inner	No
	Galah	Medium bird	Outer	Yes
	Mouse	Mouse	Inner	No
	Blue wing Parrot	Small bird	Inner	No
	Magpie	Medium bird	Inner	Yes
82	Turkey	Large bird	Outer	Yes
	White-striped Freetail Bat	Bat	Inner	No
	Magpie	Medium bird	Inner	Yes
	Magpie	Medium bird	Outer	Yes
	Mouse	Mouse	Inner	No
	Nankeen Kestrel	Medium bird	Inner	Yes
	Blue wing Parrot	Small bird	Inner	Yes
85	Turkey	Large bird	Outer	Yes
	Mouse	Mouse	Inner	Yes
	Magpie	Medium bird	Inner	Yes
	Mouse	Mouse	Inner	No
	Galah	Medium bird	Outer	No
	Magpie	Medium bird	Outer	Yes
	White-striped Freetail Bat	Bat	Inner	Yes
	Blue wing Parrot	Small bird	Inner	No
70	Turkey	Large bird	Outer	Yes
	White-striped Freetail Bat	Bat	Inner	No
	Galah	Medium bird	Inner	Yes
	Magpie	Medium bird	Outer	Yes
	Blue wing Parrot	Small bird	Inner	No
	Mouse	Mouse	Inner	No
	Magpie	Medium bird	Inner	Yes

Turbine #	Carcass	Carcass type	Search area	Found (Yes / No)
99	Turkey	Large bird	Outer	Yes
	White-striped Freetail Bat	Bat	Inner	No
	Galah	Medium bird	Outer	Yes
	Mouse	Mouse	Inner	No
	Magpie	Medium bird	Inner	Yes
	Magpie	Medium bird	Outer	Yes
	Blue-wing Parrot	Small bird	Inner	Yes
93	Turkey	Large bird	Outer	Yes
	White-striped Freetail Bat	Bat	Inner	No
	Blue-wing Parrot	Small bird	Inner	Yes
	Galah	Medium bird	Outer	Yes
	Mouse	Mouse	Inner	No
	Magpie	Medium bird	Inner	Yes

Appendix 6. Results of searcher efficiency trial – Summer 2014

Turbine #	Carcass	Carcass type	Search area	Found (Yes / No)
100	Turkey	Large bird	Outer	Yes
	Gould's Wattled Bat	Bat	Inner	Yes
	Magpie	Medium bird	Inner	Yes
	Rosella	Medium bird	Inner	Yes
	Galah	Medium bird	Outer	No
	Blue wing Parrot	Small bird	Inner	No
	Gould's Wattled Bat	Bat	Inner	No
133	Turkey	Large bird	Outer	Yes
	Magpie	Medium bird	Outer	Yes
	Gould's Wattled Bat	Bat	Inner	Yes
	Galah	Medium bird	Inner	Yes
	Rosella	Medium bird	Inner	Yes
	Gould's Wattled Bat	Bat	Inner	Yes
	Blue wing Parrot	Small bird	Inner	No
112	Turkey	Large bird	Outer	Yes
	Gould's Wattled Bat	Bat	Inner	No
	Sparrow	Small bird	Inner	Yes
	Magpie	Medium bird	Outer	Yes
	Gould's Wattled Bat	Bat	Inner	Yes
	Galah	Medium bird	Inner	Yes
	Rosella	Medium bird	Inner	Yes
	Blue wing Parrot	Small bird	Inner	No
118	Turkey	Large bird	Outer	Yes
	Sparrow	Small bird	Inner	Yes
	Rosella	Medium bird	Inner	Yes
	Gould's Wattled Bat	Bat	Inner	Yes
	Blue wing Parrot	Small bird	Inner	No
	Magpie	Medium bird	Outer	Yes
132	Turkey	Large bird	Outer	Yes
	Galah	Medium bird	Inner	Yes
	Magpie	Medium bird	Outer	No
	Blue wing Parrot	Small bird	Inner	Yes
	Sparrow	Small bird	Inner	Yes
	Gould's Wattled Bat	Bat	Inner	No
	Rosella	Medium bird	Inner	No
88	Turkey	Large bird	Outer	Yes
	Rosella	Medium bird	Inner	Yes
	Galah	Medium bird	Outer	No
	Sparrow	Small bird	Inner	Yes
	Gould's Wattled Bat	Bat	Inner	Yes
	Blue-wing Parrot	Small bird	Inner	No
	Magpie	Medium bird	Inner	Yes
140	Turkey	Large bird	Outer	Yes
	Rosella	Medium bird	Inner	Yes
	Skylark	Small bird	Inner	Yes
	Galah	Medium bird	Outer	Yes
	Gould's Wattled Bat	Bat	Inner	No
	Sparrow	Small bird	Inner	Yes
	Magpie	Medium bird	Inner	Yes

Turbine #	Carcass	Carcass type	Search area	Found (Yes / No)
135	Turkey	Large bird	Outer	Yes
	Gould's Wattled Bat	Bat	Inner	Yes
	Galah	Medium bird	Outer	Yes
	Skylark	Small bird	Inner	Yes
	Rosella	Medium bird	Inner	Yes
	Magpie	Medium bird	Outer	Yes
	Blue-wing Parrot	Small bird	Inner	Yes
139	Turkey	Large bird	Outer	Yes
	Gould's Wattled Bat	Bat	Inner	No
	Rosella	Medium bird	Inner	Yes
	Blue-wing Parrot	Small bird	Inner	No
	Galah	Medium bird	Outer	Yes
	Sparrow	Small bird	Inner	Yes
	Magpie	Medium bird	Inner	Yes

Appendix 7. Estimates of bird and bat mortality at each turbine searched during autumn 2013.

Turbine #	Large birds	Medium birds	Small birds	Bats	All birds
1	0.00	0.00	0.00	0.00	0.00
7	0.00	7.83	0.00	0.00	7.83
10	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00
21	0.00	7.83	0.00	0.00	7.83
25	0.00	9.28	0.00	7.35	9.28
29	0.00	0.00	0.00	0.00	0.00
32	0.00	34.21	0.00	6.43	34.21
34	0.00	0.00	0.00	6.43	0.00
35	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00
37	0.00	9.86	0.00	0.00	9.86
48	0.00	0.00	0.00	0.00	0.00
54	0.00	8.41	0.00	0.00	8.41
55	0.00	0.00	0.00	0.00	0.00
56	0.00	0.00	0.00	0.00	0.00
58	0.00	0.00	0.00	0.00	0.00
59	0.00	0.00	0.00	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00
64	0.00	0.00	0.00	0.00	0.00
69	0.00	0.00	0.00	0.00	0.00
70	0.00	0.00	0.00	0.00	0.00
72	0.00	0.00	0.00	6.20	0.00
73	0.00	9.86	0.00	0.00	9.86
75	0.00	26.10	0.00	0.00	26.10
82	0.00	13.91	0.00	0.00	13.91
85	0.00	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00
88	0.00	0.00	0.00	0.00	0.00
93	0.00	0.00	0.00	0.00	0.00
99	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00
101	0.00	0.00	0.00	0.00	0.00
103	0.00	0.00	0.00	0.00	0.00
104	1.00	16.81	0.00	0.00	17.81
105	0.00	0.00	0.00	0.00	0.00
111	0.00	0.00	0.00	0.00	0.00
112	0.00	0.00	0.00	0.00	0.00
116	0.00	0.00	0.00	0.00	0.00
118	0.00	0.00	0.00	0.00	0.00
125	0.00	7.83	0.00	0.00	7.83
128	0.00	15.65	0.00	0.00	15.65

Turbine #	Large birds	Medium birds	Small birds	Bats	All birds
132	0.00	0.00	0.00	0.00	0.00
133	0.00	0.00	0.00	0.00	0.00
135	0.00	0.00	7.15	0.00	7.15
139	0.00	0.00	0.00	0.00	0.00
140	0.00	0.00	0.00	0.00	0.00
Mean / turbine	0.02	3.49	0.15	0.55	3.66
Standard error	0.02	1.06	0.15	0.27	1.06

Appendix 8. Estimates of bird and bat mortality at each turbine searched during winter 2013.

Turbine #	Large birds	Medium birds	Small birds	Bats	All birds
1	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00
10	1.00	0.00	0.00	0.00	1.00
15	0.00	6.64	0.00	0.00	6.64
21	0.00	0.00	0.00	0.00	0.00
25	0.00	6.42	0.00	0.00	6.42
29	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00
35	0.00	6.64	0.00	0.00	6.64
36	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00
48	0.00	0.00	0.00	0.00	0.00
54	0.00	0.00	0.00	0.00	0.00
55	0.00	0.00	0.00	0.00	0.00
56	0.00	0.00	0.00	0.00	0.00
58	0.00	0.00	0.00	0.00	0.00
59	0.00	0.00	0.00	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00
64	0.00	7.30	0.00	0.00	7.30
69	0.00	0.00	0.00	0.00	0.00
70	0.00	0.00	0.00	0.00	0.00
72	0.00	0.00	0.00	0.00	0.00
73	0.00	0.00	0.00	0.00	0.00
75	0.00	6.19	0.00	0.00	6.19
82	0.00	6.19	0.00	0.00	6.19
85	0.00	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00
88	0.00	0.00	0.00	0.00	0.00
93	0.00	7.30	0.00	0.00	7.30
99	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00
101	0.00	0.00	0.00	0.00	0.00
103	0.00	0.00	0.00	0.00	0.00
104	1.00	13.27	0.00	0.00	14.27
105	0.00	0.00	0.00	0.00	0.00
111	0.00	0.00	0.00	0.00	0.00
112	0.00	0.00	0.00	0.00	0.00
116	0.00	0.00	0.00	0.00	0.00
118	0.00	0.00	0.00	0.00	0.00
125	0.00	0.00	0.00	0.00	0.00
128	0.00	0.00	0.00	0.00	0.00

Turbine #	Large birds	Medium birds	Small birds	Bats	All birds
132	0.00	0.00	9.71	0.00	9.71
133	0.00	0.00	0.00	0.00	0.00
135	0.00	0.00	0.00	0.00	0.00
139	1.00	0.00	0.00	0.00	1.00
140	0.00	6.19	0.00	0.00	6.19
Mean / turbine	0.06	1.38	0.20	0.00	1.64
Standard error	0.04	0.44	0.20	0.00	0.48

Appendix 9. Estimates of bird and bat mortality at each turbine searched during spring 2013.

Turbine #	Large birds	Medium birds	Small birds	Bats	All birds
1	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	9.30	0.00	9.30
35	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00
48	0.00	1.30	0.00	0.00	1.30
54	0.00	0.00	0.00	0.00	0.00
55	0.00	0.00	0.00	0.00	0.00
56	0.00	0.00	0.00	0.00	0.00
58	0.00	0.00	0.00	0.00	0.00
59	0.00	0.00	0.00	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00
64	0.00	0.00	0.00	0.00	0.00
69	0.00	1.39	0.00	0.00	1.39
70	0.00	0.00	0.00	0.00	0.00
72	0.00	2.50	0.00	0.00	2.50
73	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00
85	0.00	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00
88	0.00	0.00	0.00	0.00	0.00
93	0.00	0.00	0.00	0.00	0.00
99	0.00	1.68	0.00	0.00	1.68
100	0.00	1.59	0.00	0.00	1.59
101	0.00	0.00	0.00	0.00	0.00
103	0.00	0.00	0.00	0.00	0.00
104	0.00	2.83	0.00	0.00	2.83
105	0.00	0.00	0.00	0.00	0.00
111	1.00	0.00	0.00	0.00	1.00
112	0.00	0.00	0.00	0.00	0.00
116	0.00	0.00	0.00	0.00	0.00
118	0.00	1.54	0.00	0.00	1.54
125	0.00	1.63	0.00	0.00	1.63
128	0.00	0.00	0.00	0.00	0.00

Turbine #	Large birds	Medium birds	Small birds	Bats	All birds
132	0.00	0.00	0.00	0.00	0.00
133	0.00	3.08	0.00	0.00	3.08
135	0.00	0.00	0.00	0.00	0.00
139	0.00	0.00	0.00	0.00	0.00
140	0.00	0.00	0.00	0.00	0.00
Mean / turbine	0.02	0.37	0.19	0.00	0.58
Standard error	0.02	0.12	0.19	0.00	0.22

Appendix 10. Estimates of bird and bat mortality at each turbine searched during summer 2014.

Turbine #	Large birds	Medium birds	Small birds	Bats	All birds
1	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	48.00	0.00	48.00
36	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00
48	0.00	0.00	0.00	0.00	0.00
54	0.00	0.00	0.00	0.00	0.00
55	0.00	0.00	0.00	0.00	0.00
56	0.00	0.00	0.00	0.00	0.00
58	0.00	0.00	0.00	0.00	0.00
59	0.00	0.00	0.00	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00
64	0.00	0.00	0.00	0.00	0.00
69	0.00	4.47	0.00	0.00	4.47
70	0.00	0.00	0.00	0.00	0.00
72	0.00	1.83	0.00	0.00	1.83
73	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	48.00	0.00	48.00
82	0.00	1.82	45.54	0.00	47.36
85	0.00	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00
88	0.00	0.00	0.00	0.00	0.00
93	0.00	5.79	0.00	0.00	5.79
99	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00
101	0.00	0.00	0.00	0.00	0.00
103	0.00	0.00	0.00	0.00	0.00
104	0.00	0.00	0.00	0.00	0.00
105	0.00	4.59	0.00	0.00	4.59
111	0.00	0.00	0.00	0.00	0.00
112	0.00	0.00	0.00	0.00	0.00
116	0.00	0.00	0.00	20.47	0.00
118	0.00	0.00	46.77	21.03	46.77
125	0.00	0.00	0.00	0.00	0.00
128	0.00	0.00	0.00	0.00	0.00

Turbine #	**Large birds**	**Medium birds**	**Small birds**	**Bats**	**All birds**
132	0.00	0.00	0.00	0.00	0.00
133	0.00	0.00	0.00	0.00	0.00
135	0.00	0.00	0.00	0.00	0.00
139	0.00	0.00	0.00	0.00	0.00
140	0.00	0.00	0.00	0.00	0.00
Mean / turbine	0.00	0.39	3.92	0.86	4.31
Standard error	0.00	0.18	1.90	0.60	1.91

Appendix 11. Estimates of bird and bat mortality at each turbine searched over all 12 months.

Turbine #	Large birds	Medium birds	Small birds	Bats	All birds
1	0.00	0.00	0.00	0.00	0.00
7	0.00	7.83	0.00	0.00	7.83
10	1.00	0.00	0.00	0.00	1.00
15	0.00	6.64	0.00	0.00	6.64
21	0.00	7.83	0.00	0.00	7.83
25	0.00	15.70	0.00	7.35	15.70
29	0.00	0.00	0.00	0.00	0.00
32	0.00	34.21	0.00	6.43	34.21
34	0.00	0.00	9.30	6.43	9.30
35	0.00	6.64	48.00	0.00	54.64
36	0.00	0.00	0.00	0.00	0.00
37	0.00	9.86	0.00	0.00	9.86
48	0.00	1.30	0.00	0.00	1.30
54	0.00	8.41	0.00	0.00	8.41
55	0.00	0.00	0.00	0.00	0.00
56	0.00	0.00	0.00	0.00	0.00
58	0.00	0.00	0.00	0.00	0.00
59	0.00	0.00	0.00	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00
64	0.00	7.30	0.00	0.00	7.30
69	0.00	5.86	0.00	0.00	5.86
70	0.00	0.00	0.00	0.00	0.00
72	0.00	4.33	0.00	6.20	4.33
73	0.00	9.86	0.00	0.00	9.86
75	0.00	32.29	48.00	0.00	80.29
82	0.00	21.92	45.54	0.00	67.46
85	0.00	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00
88	0.00	0.00	0.00	0.00	0.00
93	0.00	13.09	0.00	0.00	13.09
99	0.00	1.68	0.00	0.00	1.68
100	0.00	1.59	0.00	0.00	1.59
101	0.00	0.00	0.00	0.00	0.00
103	0.00	0.00	0.00	0.00	0.00
104	2.00	32.91	0.00	0.00	34.91
105	0.00	4.59	0.00	0.00	4.59
111	1.00	0.00	0.00	0.00	1.00
112	0.00	0.00	0.00	0.00	0.00
116	0.00	0.00	0.00	20.47	0.00
118	0.00	1.54	46.77	21.03	48.31
125	0.00	9.46	0.00	0.00	9.46
128	0.00	15.65	0.00	0.00	15.65

Turbine #	Large birds	Medium birds	Small birds	Bats	All birds
132	0.00	0.00	9.71	0.00	9.71
133	0.00	3.08	0.00	0.00	3.08
135	0.00	0.00	7.15	0.00	7.15
139	1.00	0.00	0.00	0.00	1.00
140	0.00	6.19	0.00	0.00	6.19
Mean / turbine	0.10	5.62	4.47	1.41	10.19
Standard error	0.05	1.28	1.90	0.65	2.61