Macarthur Wind Farm

Bat and Avifauna Mortality Monitoring

March 2014 to February 2015

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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 suspected to have been killed by collision with the blades of turbines and to estimate annual mortality per turbine and over the entire wind farm. Additionally, this monitoring program aimed to ascertain the impact of the wind farm on specified species, particularly the Brolga and Southern Bent-wing Bat, which trigger the requirement for responsive mitigation.

The 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 Ecologists 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 undertaken.

Following a review of mortality estimates from the first 12 months of monitoring (Wood 2014a), it was decided to increase the frequency of carcass searches from monthly to weekly in order to improve the accuracy of mortality estimates by reducing the probability that carcasses will be scavenged prior to the search being undertaken. This report details the results of bird and bat mortality monitoring from March 2014 to the end of February 2015 and compares mortality estimates from the previous 12 months of monitoring to examine any changes in bird and bat mortality over the two year monitoring period.

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 76 individual birds from 16 species, consisting of 24 carcasses and 52 feather spots, and nine bats from two species were found during carcass searches. A carcass of a Little Red Flying Fox was also found during carcass searches and categorised as a bat for the purposes of analyses. An additional 13 birds and one bat was found incidentally by maintenance staff and others not involved in scheduled carcass searches. Small birds suffered the highest rates of mortality (10.33 / turbine / year), followed by medium sized birds (2.87 / turbine / year) and large birds (0.20 / turbine / year). All birds averaged 13.40 birds / turbine / year and bat mortality averaged 3.08 / turbine / year. Overall bird and bat mortality varied significantly between seasons with most bird mortalities occurring in spring and most bat mortalities occurring in autumn.

Introduced species accounted for 42.10% of bird fatalities found during carcass searches which, after applying correction factors for searcher efficiency and scavenging rates, corresponded to 75.30% of the calculated mortality estimate of all birds over the wind farm. The annual mortality of native birds was estimated at 3.31 birds per turbine per year, equating to an estimate of 464.02 ± 109.20 birds over the wind farm. Annual mortality of raptors was estimated at 1.11 per turbine, equating to a total mortality of 154.88 ± 39.20 over the wind farm.

There was no significant difference in the mortality of birds or bats since 2013. However, seasonal mortality of birds varied significantly between years. In 2013 the greatest mortality of birds occurred during autumn and summer and was lowest in spring whilst in 2014, bird mortalities were significantly greater in spring than in all other seasons when mortality was relatively similar in each season.

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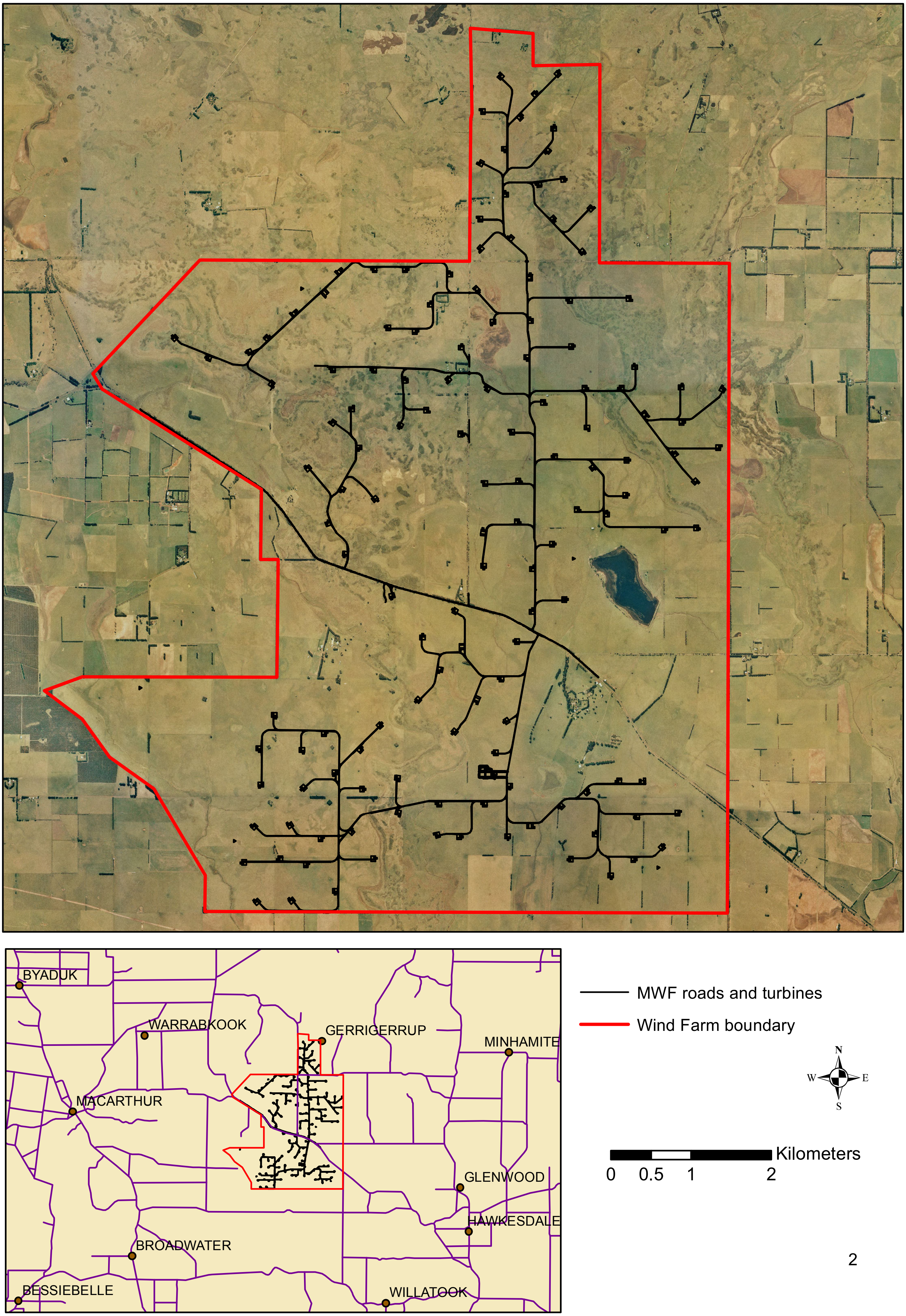
1.0 INTRODUCTION

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 was 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 with monthly searches for dead birds and bats, or evidence of such, within a plot (230 x 230m) centred around a sample of 48 turbines. During the first 12 months of monitoring, overall bird mortality was estimated at 10.19 birds per turbine per year and that of bats was estimated at 1.41 per turbine per year (Wood 2014). However, these estimates of mortality were considered inaccurate due to the high rates of scavenging and removal of carcasses prior to searches being undertaken. Whilst a correction factor was applied to estimates of mortality to account for the removal of carcasses by scavengers, the high rates of scavenging that occurred resulted in a high reliance on correction factors rather than actual mortalities in estimates of seasonal and annual bird and bat mortality over the wind farm. The frequency of carcass searches was subsequently increased to weekly at a sample of 15 turbines from March 2014 to improve the accuracy of mortality estimates.

The following report details the results of bird and bat mortality monitoring undertaken at the Macarthur Wind Farm from March 2014 to February 2015, documenting the bird and bat fatalities recorded during this period 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, including any remains such as feather spots, found under wind turbines were used to calculate an estimate of seasonal and annual mortality.

2.1 Carcass Searches

Following a review of the mortality estimates calculated (Wood 2014) and results of scavenger trials undertaken during the first 12 months of monitoring in accordance with the requirements of the BAM Plan, it was apparent that mortality estimates based on monthly searches may have been inaccurate due to the frequent scavenging of bird and bat carcasses. In March 2014 a trial was undertaken to examine bird and bat mortality when turbines were searched daily. This trial was undertaken at a sample of six turbines over eight consecutive days. From the 48 carcass searches conducted, carcasses of two White-striped Freetail Bats and one Eurasian Skylark were found at two turbines. It was subsequently decided to increase the frequency of carcass searches from monthly to weekly from April 2014 to reduce the reliance on correction factors for scavenging rates and improve the accuracy of mortality estimates. The number of turbines searched was reduced from 48 to 15 but was considered an adequate sample given the increased accuracy of mortality estimates and greater number of carcass searches undertaken each month. The 15 turbines searched were randomly selected from the original subset of 48 turbines that were searched during the first 12 months of monitoring. The locations of turbines used for carcass searches during the second 12 months of monitoring from April 2014 to February 2015 are shown in Figure 2. Carcass searches were undertaken according to a weekly schedule, attempting as far as possible to maintain the same schedule and time interval between consecutive searches of the same turbine. 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 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 15 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 $1m^2$ 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 (Wood 2014b, 2014c, 2014d, 2015).

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

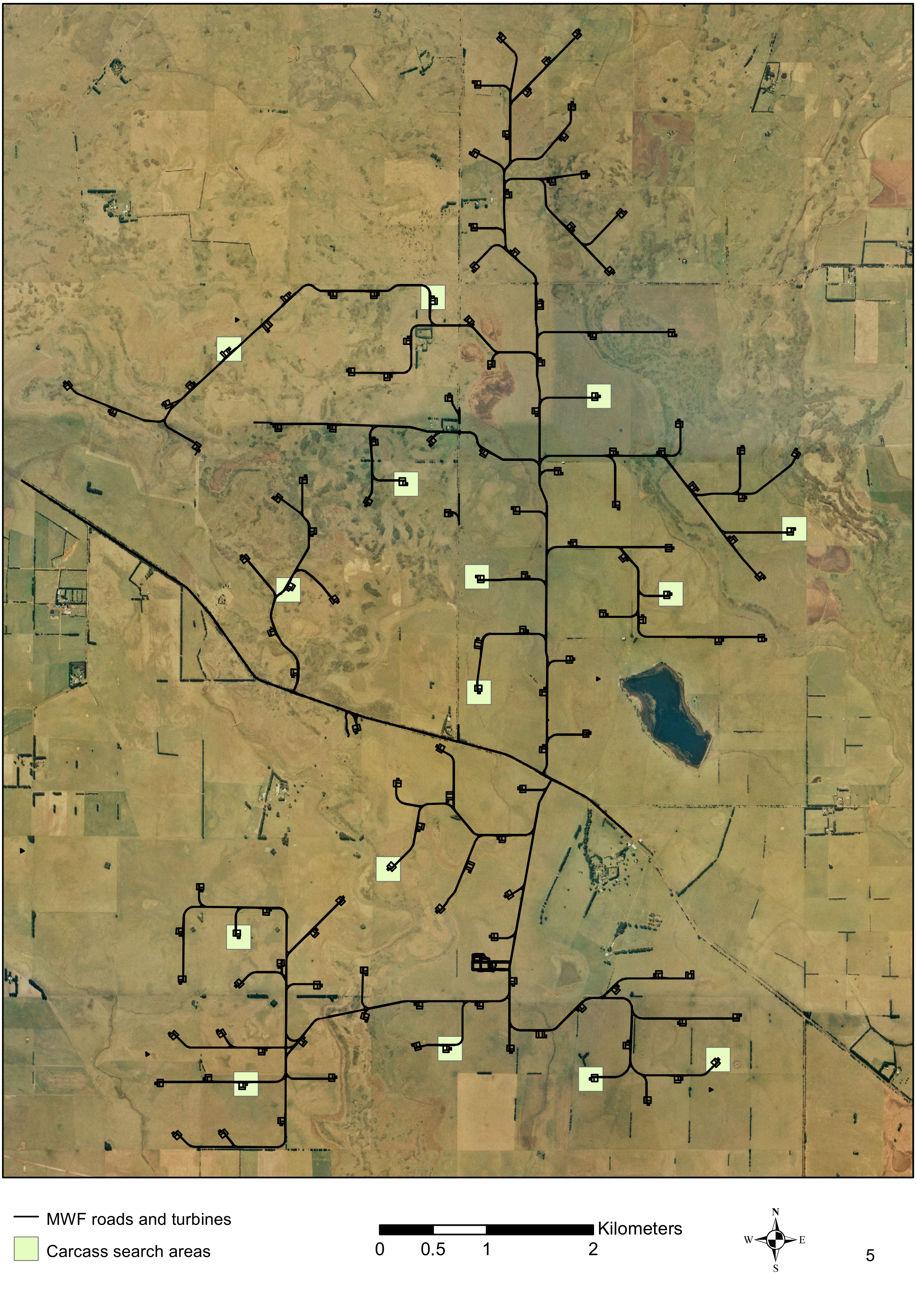
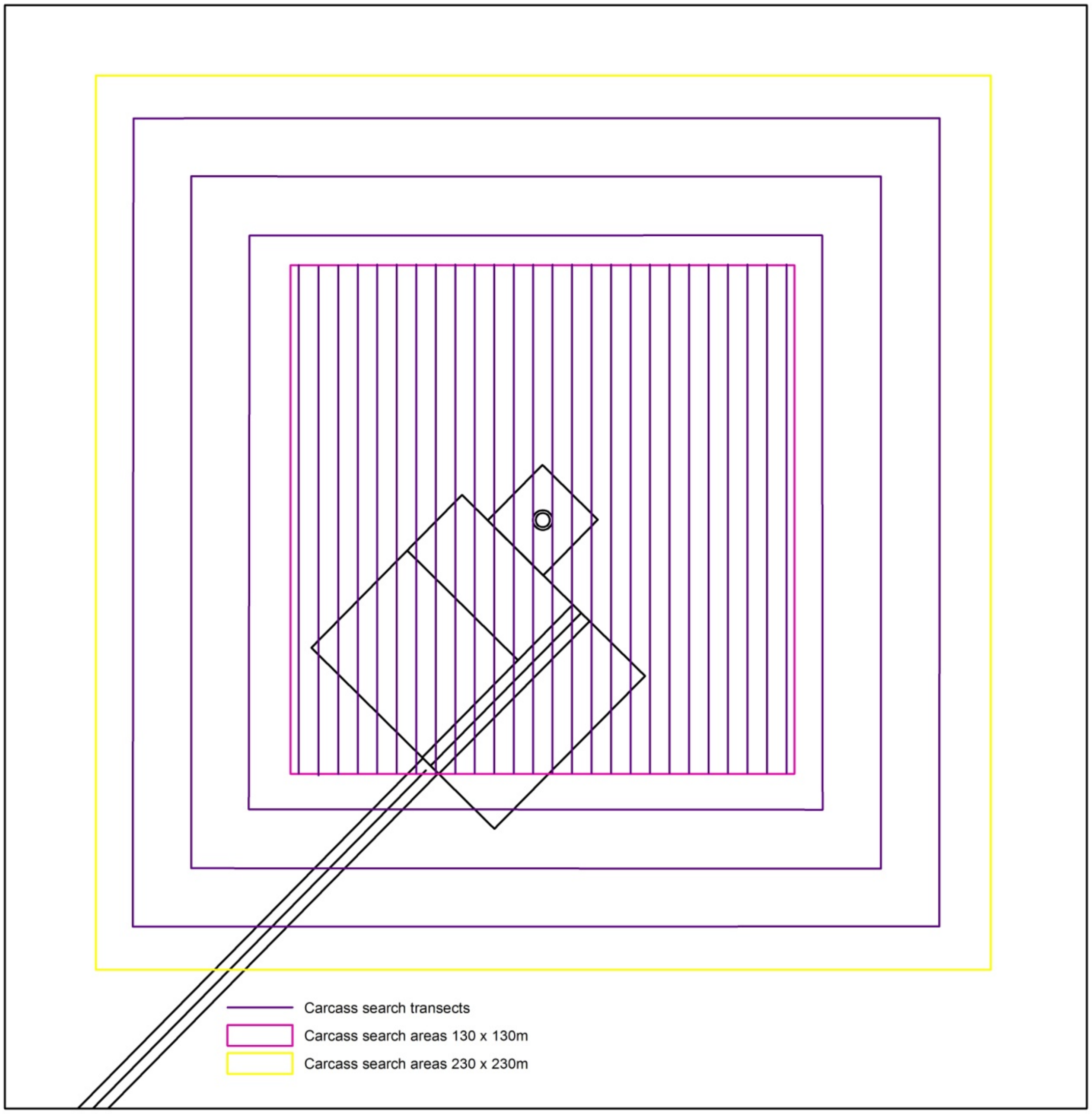


Figure 3. Representation of transect locations within carcass search plots.



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. 10007051), 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 as they were of similar size and colour to most bat species that occur on the wind farm. 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. 10007051. 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 week as well as per turbine per season and per turbine per year. The mean seasonal and annual mortality was calculated from weekly estimates in each season and from all weeks combined. Total annual mortality at each turbine was calculated by summing weekly mortality estimates for all birds and bats and separately for large, medium and small birds.

To enable comparisons with mortality estimates at other wind farms in which finds of feather spots or partial carcasses are excluded from analyses, two estimates of mortality were calculated; the first included carcasses and feather spots in analyses and the second estimated mortality from finds of whole carcasses only, excluding feather spots or partial carcasses from analyses. The first mortality estimate applied a scavenging correction factor based on the average time for carcasses and any remains such as feather spots to be considered no longer detectable whilst the second estimate was calculated from a scavenging rate of carcasses only regardless of any remains that may still be detectable during a carcass search.

Mortality was also estimated separately for native bird species by excluding introduced species from analyses and also for raptors by excluding all other bird species. Feather spots were included in these analyses.

3.0 RESULTS

3.1 Carcass Searchers

Weekly carcass searches at the 15 selected turbines commenced in April 2014 following a trial of daily searches at six turbines in March 2014. A total of 705 weekly carcass searches (47 searches of 15 turbines) were conducted over the subsequent 11 months from early April 2014 to the end of February 2015. Results from the 48 carcass searches undertaken daily at six turbines (Turbines 34, 35, 85, 99, 104 and 135) were also included in estimates of mortality at the wind farm.

Bird fatalities

A total of 76 bird fatalities were found during carcass searches from March 2014 to February 2015 consisting of 52 feather spots and 24 carcasses. Bird fatalities consisted of 16 species and an additional unidentified bird found only as a feather spot (Table 1). The Eurasian Skylark was the most common fatality found (36.8% of fatalities), followed by the Nankeen Kestrel (14.5%) and Australian Magpie (10.5%). No threatened bird species were found.

An additional 13 bird carcasses were found incidentally near turbines by maintenance personnel, landowners or ecologists when not undertaking scheduled carcass searches. These carcasses included seven Wedge-tailed Eagles, two Ravens, one Whistling Kite, one Brown Falcon, one Magpie and one Eurasian Skylark. One Brolga carcass was also found incidentally at the wind farm but was not believed to have been killed by blade strike as it was found within a wetland 246 m from the nearest turbine. The Department of Environment, Land, Water and Planning (formerly the Department of Sustainability and Environment) was notified immediately of the Brolga mortality. A subsequent autopsy carried out by an independent pathology recommended by the Department of Environment, Land, Water and Planning did not find any evidence of trauma such as broken bones associated with blade strike and is suspected to have died from an illness of some kind. Carcasses found incidentally were excluded from estimates of mortality.

Bat fatalities

A total of nine bat carcasses from two species and one Little Red Flying Fox carcass were found during carcass searches from March 2014 to February 2015 (Table 1). The White-striped Freetail Bat was the most common bat fatality found (80% of fatalities). A carcass of a Southern Bent-wing Bat was also found during a carcass search. This species is Critically Endangered under the Environment Protection and Biodiversity Conservation Act 1999 and is listed as threatened under the Victorian Flora and Fauna Guarantee Act 1988. The Department of Environment, Land, Water and Planning was notified immediately and the carcass was autopsied by an independent pathology recommended by the Department of Environment, Land, Water and Planning. An additional carcass of a Gould's Wattled Bat was found incidentally near a turbine. This carcass was excluded from estimates of mortality.

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

Common name	Scientific name	No. carcasses	No. feather spots	Total
Australian Magpie	*Cracticus tibicen*	2	6	8
Barn Owl	*Tyto alba*	0	1	1
Brown Falcon	*Falco beringora*	3	1	4
Common Starling	*Sturnus vulgaris*	1	0	1
Corella sp.	*Cacatua tenuirostris*	0	1	1
Eurasian Skylark	*Alauda arvensis*	12	16	28
European Gold Finch	*Carduelis carduelis*	1	2	3
Magpie Lark	*Grallina cyanoleuca*	0	4	4
Nankeen Kestrel	*Falco cenchroides*	3	8	11
Pacific Black Duck	*Anas superciliosa*	0	1	1
Purple Swamp Hen	*Porphyrio porphyrio*	0	1	1
Raven sp.	*Corvus sp.*	0	5	5
Red-rumped Parrot	*Psephotus haematonotus*	0	3	3
Straw-necked Ibis	*Threskiornis spinicollis*	0	1	1
Stubble Quail	*Coturnix pectoralis*	0	1	1
Wedge-tailed Eagle	*Aquila audax*	2	0	2
Unidentified bird species		0	1	1
Avian Sub-total		**24**	**52**	**76**
Little Red Flying Fox	*Pteropus scapulatus*	1	0	1
Southern Bent-wing Bat	*Miniopterus schreibersii*	1	0	1
White-striped Freetail Bat	*Tadarida australis*	8	0	8
Bat Sub-total		**10**	**0**	**10**

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 2014

Table 2. Searcher efficiency for each carcass type and search area – Autumn 2014

Carcass type	**Search area**	**Number of carcasses available**	**Number found by Ryan**	**Searcher efficiency (%)**
Large bird	Outer	9	9	100
Medium bird	Inner	11	11	100
	Outer	10	10	100
Small bird	Inner	15	7	46.7
Bat	Inner	17	6	35.3

Winter 2014

Table 3. Searcher efficiency for each carcass type and search area – Winter 2014

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Carcass type	**Search area**	**Number of carcasses available**	**Number found**		**Searcher efficiency (%)**	
			Alec	**Alistair**	**Alec**	**Alistair**
Large bird	Outer	9	9	9	100	100
Medium bird	Inner	11	10	11	91	100
	Outer	10	9	8	90	80
Small bird	Inner	11	9	9	82	82
Bat / Mouse	Inner	15	8	4	53	36

Spring 2014

Table 4. Searcher efficiency for each carcass type and search area – Spring 2014

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Carcass type	Search area	Number of carcasses available	Number found		Searcher efficiency (%)	
			Alec	Emma	Alec	Emma
Large bird	Outer	9	9	9	100	100
Medium bird	Inner	10	10	10	100	100
	Outer	8	8	8	100	100
Small bird	Inner	15	11	13	73	87
Bat / Mouse	Inner	8	5	6	63	75

Summer 2014/15

Table 5. Searcher efficiency for each carcass type and search area – Summer 2014/15

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Carcass type	Search area	Number of carcasses available	Number found		Searcher efficiency (%)	
			Alec	Emma	Alec	Emma
Large bird	Outer	9	9	9	100	100
Medium bird	Inner	12	12	12	100	100
	Outer	9	8	9	89	100
Small bird	Inner	18	14	16	78	89
Bat / Mouse	Inner	8	6	7	75	88

3.3 Scavenger Trials

Scavenger trials were conducted at the same 10 turbines in each season. The average carcass duration for large, medium and small birds and bats was calculated separately for each season. Carcass duration was also calculated separately for removal of the carcass and for any remains such as feather spots to be no longer detectable. Further details are provided in separate reports (Wood 2014b, 2014c, 2014d, 2015a).

The rate at which carcasses were removed by scavengers as well as the number of days for any remains such as feather spots to be no longer detectable for each carcass type in each season is shown in Figures 4 - 11. The average duration for carcass to be removed and any post-scavenging remains to be undetectable for each carcass type in each season is detailed in Tables 6 - 9. Since the majority of large bird carcasses, consisting mostly of Turkeys, were still detectable from feather spots at the end of each scavenger trial even though several carcasses had been removed, it was not possible to calculate an average carcass duration for large birds as this far exceeded the trial period of 30 days.

Figure 4. Rate of carcass removal for carcass types – Autumn 2014

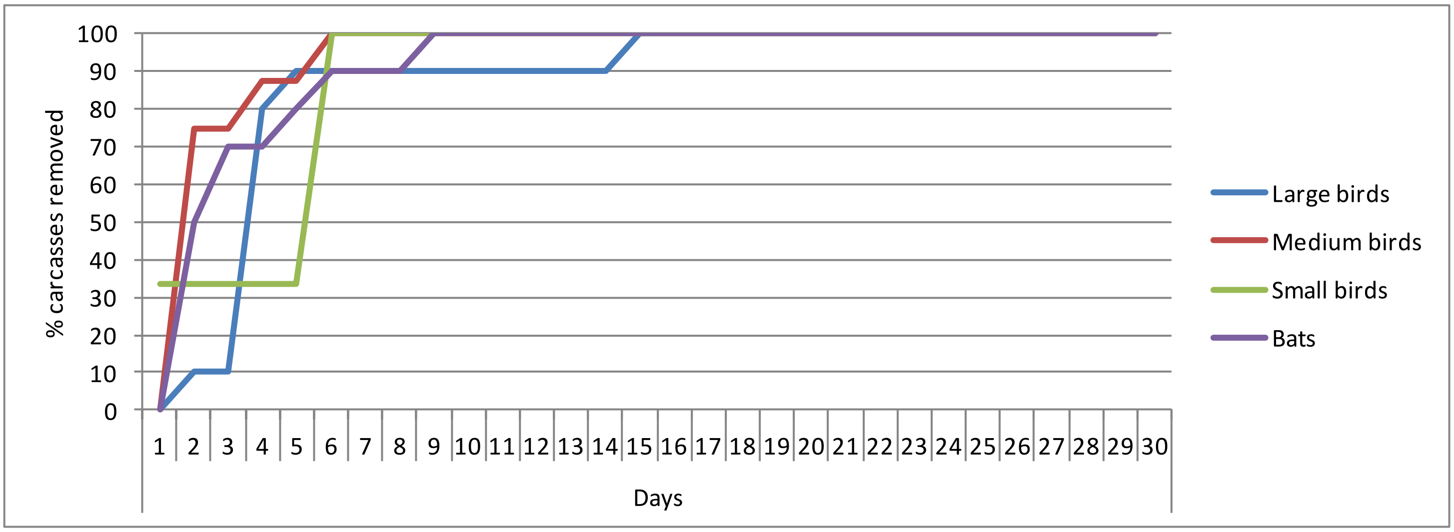


Figure 5. Rate of carcass removal and duration of any post-scavenging remains for carcass types – Autumn 2014

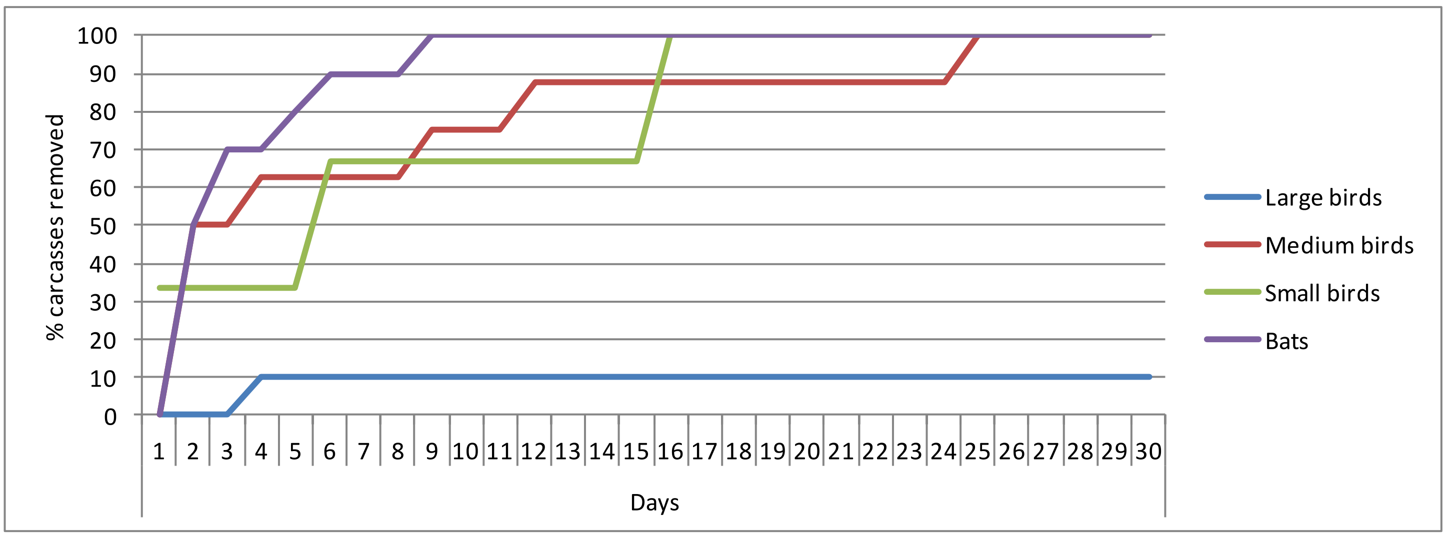


Table 6. Average duration of carcass types in Autumn 2014.

Carcass type	Average duration of carcasses only (days)	Average duration of carcasses and any post-scavenging remains (days)
Large bird (n = 10)	5.00	> 30
Medium bird (n = 8)	2.75	7.25
Small bird (n = 3)	4.33	7.66
Bat (n = 10)	3.60	3.60

Figure 6. Rate of carcass removal for carcass types – Winter 2014

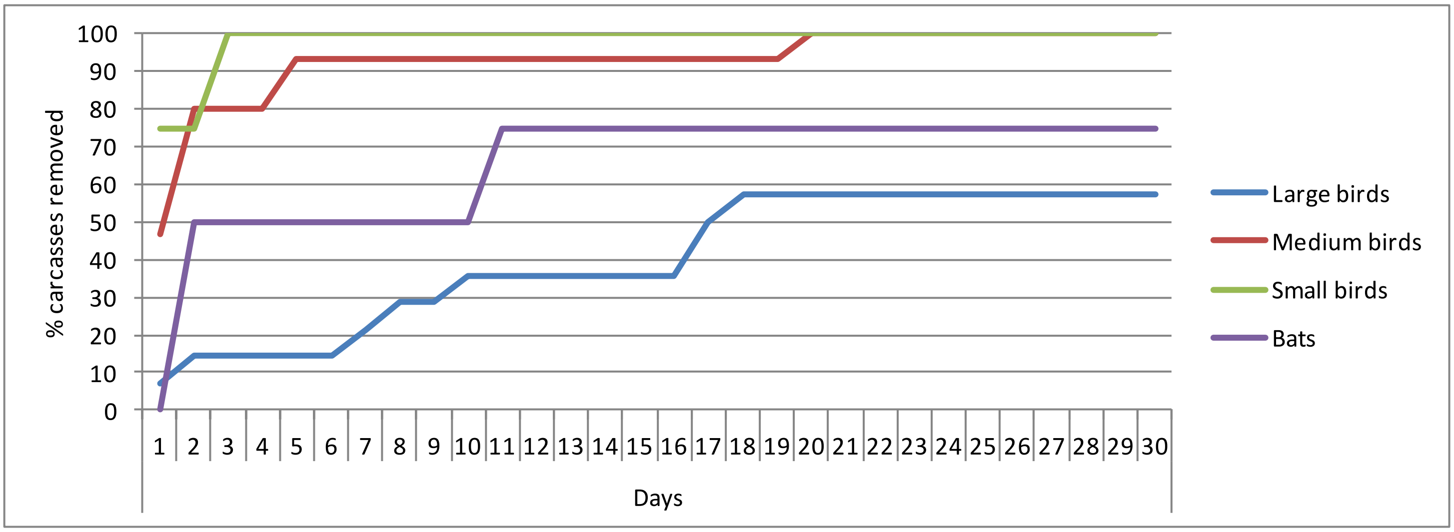


Figure 7. Rate of carcass removal and duration of any post-scavenging remains for carcass types – Winter 2014

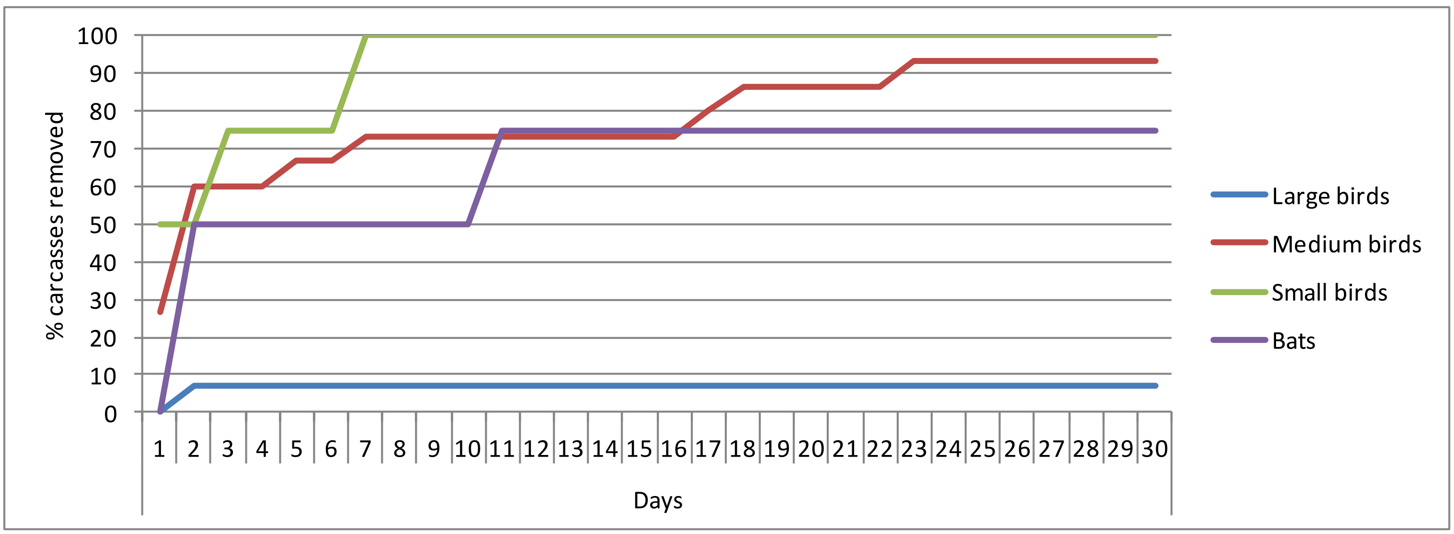


Table 7. Average duration of carcass types in Winter 2014.

Carcass type	Average duration of carcasses only (days)	Average duration of carcasses and any post-scavenging remains (days)
Large bird (n = 14)	> 30	> 30
Medium bird (n = 15)	3.13	7.60
Small bird (n = 4)	1.50	3.00
Bat (n = 4)	11.30	11.30

Figure 8. Rate of carcass removal for carcass types – Spring 2014

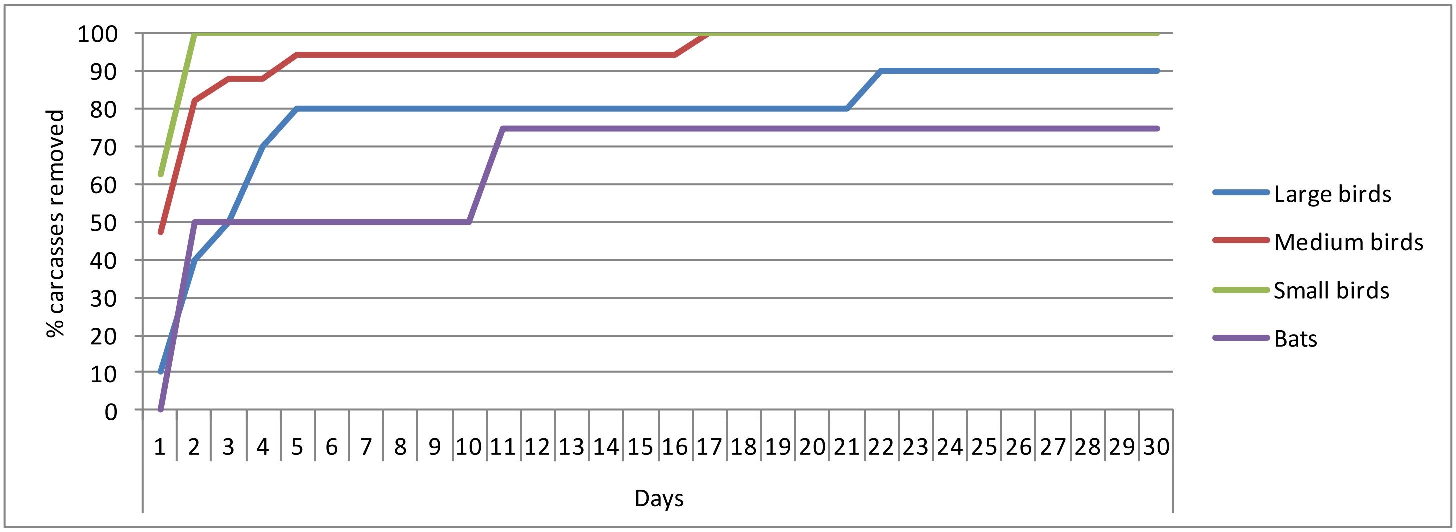


Figure 9. Rate of carcass removal and duration of any post-scavenging remains for carcass types – Spring 2014

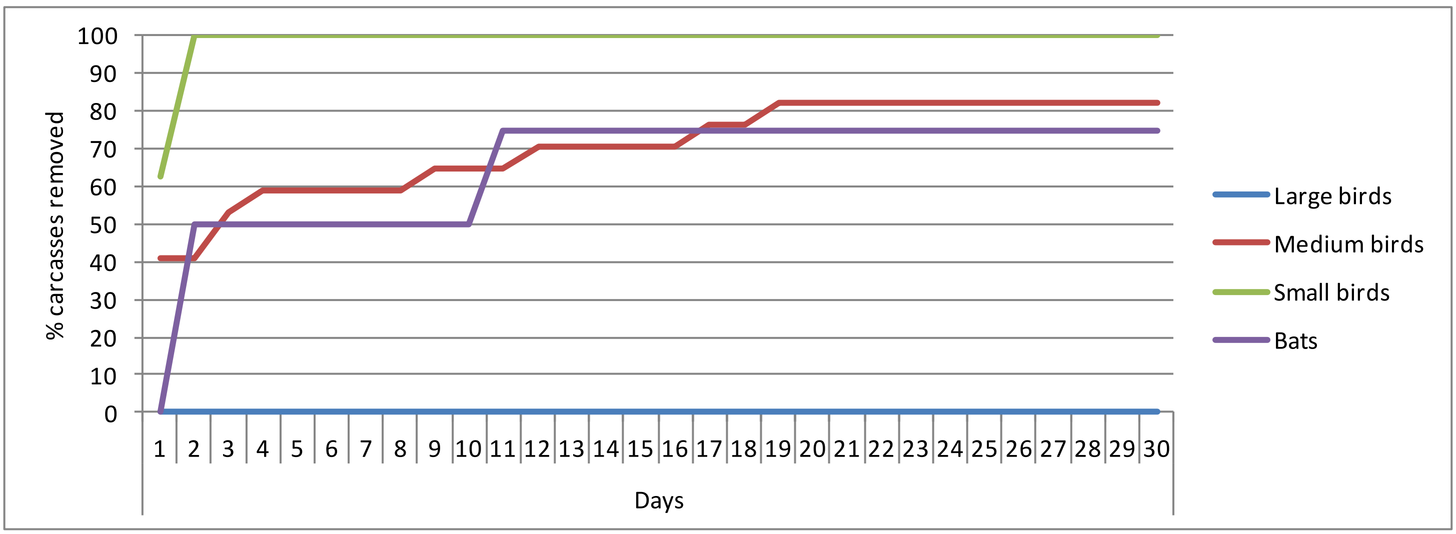


Table 8. Average duration of carcass types in Spring 2014.

Carcass type	Average duration of carcasses only (days)	Average duration of carcasses and any post-scavenging remains (days)
Large bird (n = 10)	8.33	> 30
Medium bird (n = 17)	2.64	11.70
Small bird (n = 8)	1.40	1.40
Bat (n = 1)	2.00	2.00

Figure 10. Rate of carcass removal for carcass types – Summer 2014/15

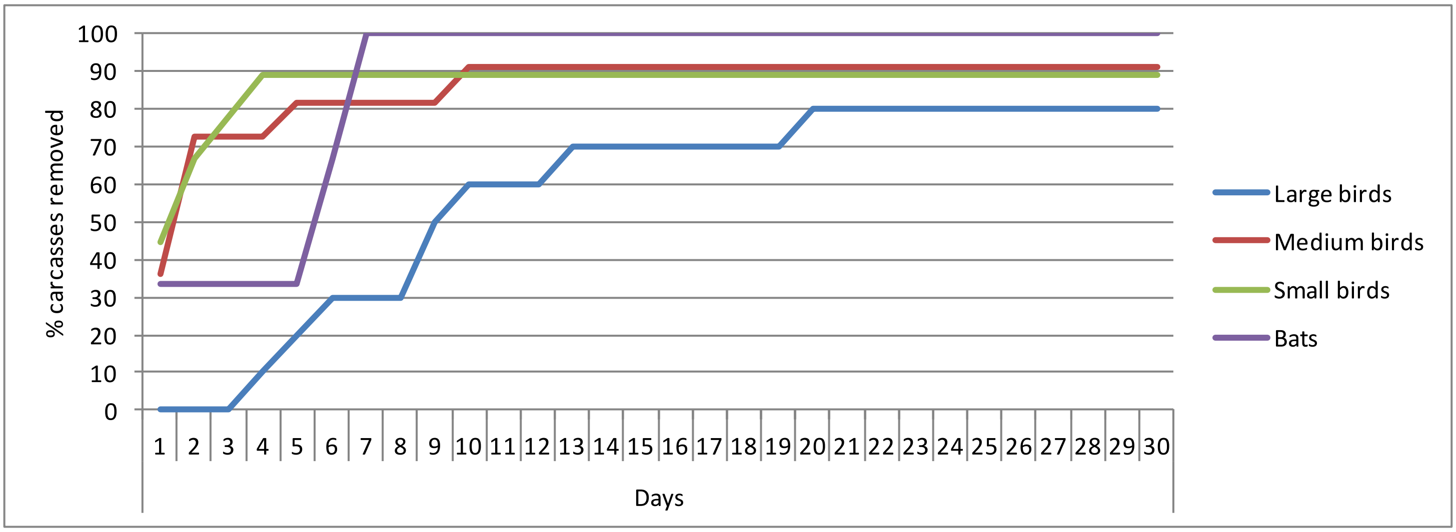


Figure 11. Rate of carcass removal and duration of any post-scavenging remains for carcass types – Summer 2014/15

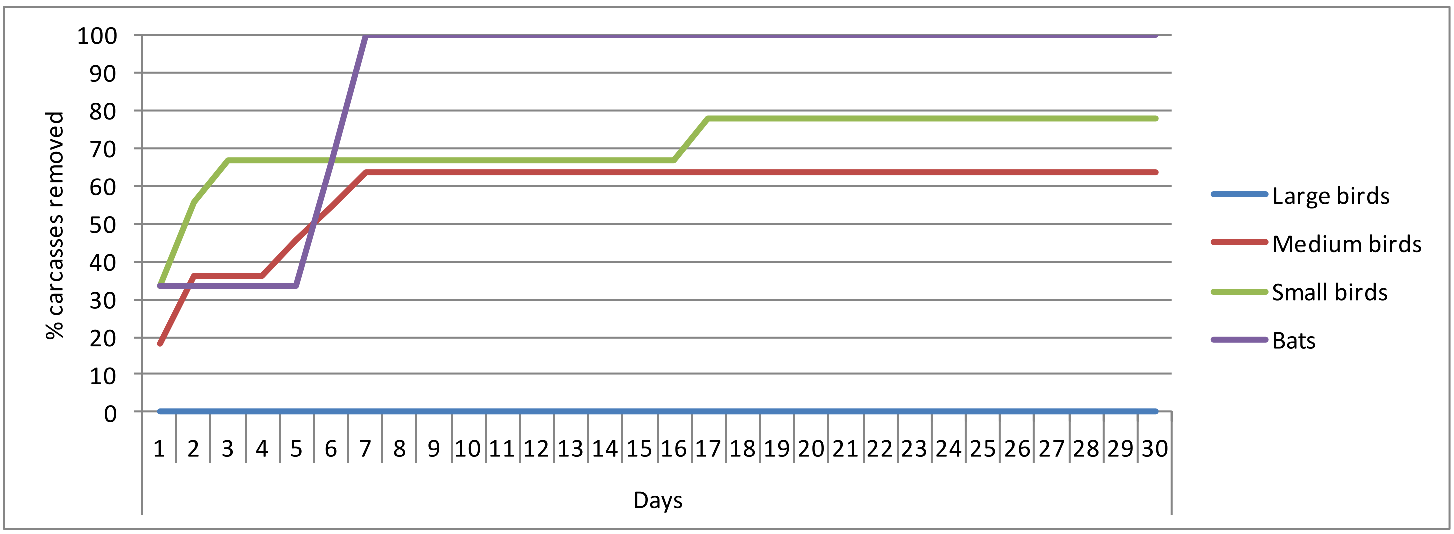


Table 9. Average duration of carcass types in Summer 2014/15.

Carcass type	Average duration of carcasses only (days)	Average duration of carcasses and any post-scavenging remains (days)
Large bird (n = 10)	17.00	> 30
Medium bird (n = 11)	6.70	20.60
Small bird (n = 9)	5.63	12.40
Bat (n = 3)	4.70	4.70

3.4 Estimates of Mortality

3.4.1 Estimates of mortality from finds of all carcasses and feather spots

Annual Mortality

The mean number of birds killed per turbine from March 2014 to end of February 2015 was estimated to be 13.40 ± 2.37. When extrapolated over the entire wind farm of 140 turbines this equates to a total of 1,875 ± 331 bird mortalities. Annual mortality varied significantly depending on the size of birds ($F = 16.510$, d.f. = 2, $p < 0.001$). Small birds accounted for the vast majority of bird mortalities averaging 10.33 ± 2.14 birds per turbine per year compared to that of large and medium birds respectively averaging 0.20 ± 0.11 and 2.87 ± 0.66 mortalities per turbine. Bat mortality was estimated at 3.08 ± 1.68 bats per turbine per year, equating to 431.20 ± 235.20 over all turbines.

Seasonal Mortality

Overall bird mortality varied significantly between seasons ($F = 11.762$, d.f. = 3, $p < 0.001$) with the greatest number of mortalities occurring during spring when an estimated 1201.02 ± 250.87 birds were killed compared to other seasons when a maximum of 266.00 ± 60.91 birds were estimated to have been killed during summer (Figure 12). This seasonal variation differed significantly between bird sizes ($F = 10.706$, d.f. = 6, $p < 0.001$). Figure 12 shows there was little seasonal variation in the mortality of large and medium birds, however, the estimated mortality of small birds ranged from 94.64 birds in autumn to 1070.35 in spring. Bat mortality also varied between seasons with highest mortalities occurring in autumn and lowest in winter. Winter bat mortality was calculated from a Flying Fox carcass rather than a micro bat fatality. Estimated mortalities of birds of each size class and 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 12. Estimated seasonal mortality of birds and bats over the wind farm

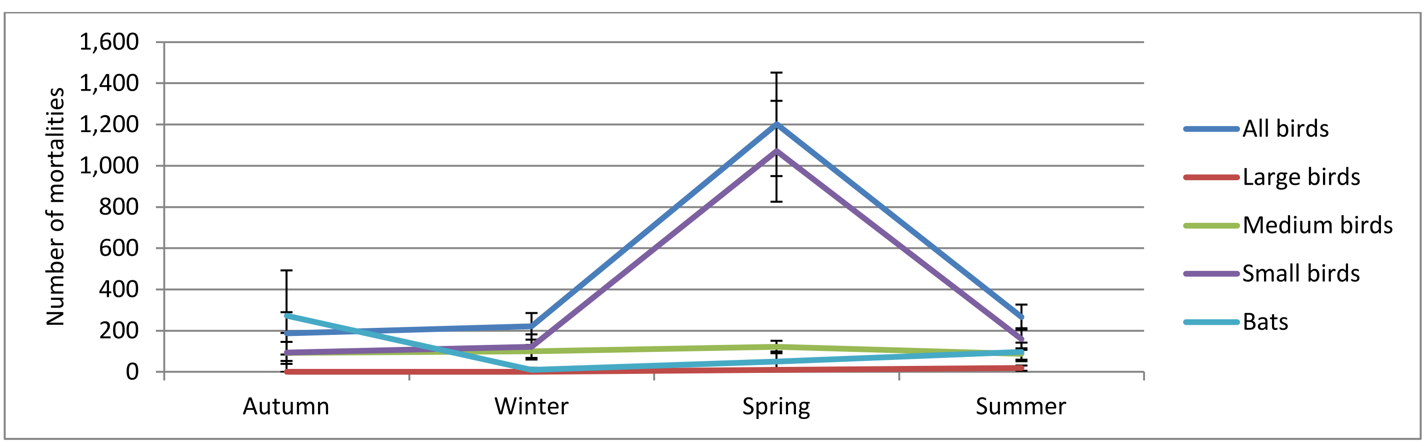


Table 10. Estimates of seasonal and annual bird and bat mortality from finds of carcasses and feather spots

Season	Group	No. of fatalities found	Mean mortality 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	0.68	0	2.12	94.64	0	296.80
	Medium birds	3	0.66	0	1.48	92.77	0	207.20
	Large birds	0	0	0	0	0	0	0
	All birds	4	1.34	0	2.91	187.41	0	407.40
	Bats	3	1.95	0	5.31	273.19	0	743.4
Winter	Small birds	5	0.87	0	1.80	121.52	0	252.00
	Medium birds	10	0.71	0.23	1.20	99.96	32.20	168.00
	Large birds	0	0	0	0	0	0	0
	All birds	15	1.58	0.59	2.57	221.48	82.60	359.80
	Bats	1	0.07	0	0.23	10.27	0	32.20
Spring	Small birds	18	7.65	3.90	11.39	1070.35	546.00	1594.60
	Medium birds	13	0.87	0.40	1.33	121.33	56.00	186.20
	Large birds	1	0.07	0	0.21	9.33	0	29.40
	All birds	32	8.58	4.73	12.42	1201.01	662.20	1738.80
	Bats	1	0.36	0	1.11	49.75	0	155.40
Summer	Small birds	14	1.14	0.34	1.95	159.97	47.60	273.00
	Medium birds	9	0.62	0.20	1.05	87.36	28.00	147.00
	Large birds	2	0.13	0	0.33	18.67	0	46.20
	All birds	25	1.90	0.97	2.83	266.00	135.80	396.20
	Bats	5	0.70	0.01	1.39	97.44	1.40	194.60
All seasons (12 months)	Small birds	38	10.33	5.75	14.91	1446.29	805.00	2087.40
	Medium birds	35	2.87	1.45	4.29	401.43	203.00	600.60
	Large birds	3	0.20	0	0.43	28.00	0	60.20
	All birds	76	13.40	8.32	18.48	1875.72	1164.80	2587.20
	Bats	10	3.08	0	6.68	430.73	0	935.20

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 Estimates of mortality from finds of whole carcasses only

Annual Mortality

Mortality estimates calculated from finds of carcasses only found that the mean number of birds killed per turbine from March 2014 to February 2015 was 6.72 ± 1.52, which equated to a total of 940.50 ± 212.80 bird fatalities when extrapolated over the entire wind farm. Of these mortalities, small birds accounted for 81.8% of mortalities compared to medium sized birds (16.2%) and large birds (2%). Annual bat mortality was estimated at 3.08 ± 1.68 bats per turbine, equating to a total of 431.20 ± 235.20 bats over all turbines.

Seasonal Mortality

Overall bird mortality varied significantly between seasons, with the greatest mortality recorded in spring when an estimated 478.98 ± 119.70 birds were killed. Bird mortality was lowest in summer when an estimated 82.46 ± 24.36 birds were killed. Bird mortality in autumn and winter was respectively estimated at 166.18 and 212.80 birds. Bat mortality also varies significantly between seasons with most mortalities occurring in autumn than in all other seasons combined (Figure 13). . Estimated mortalities of birds of each size class and 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 11.

Figure 13. Estimated seasonal mortality of birds and bats over the wind farm

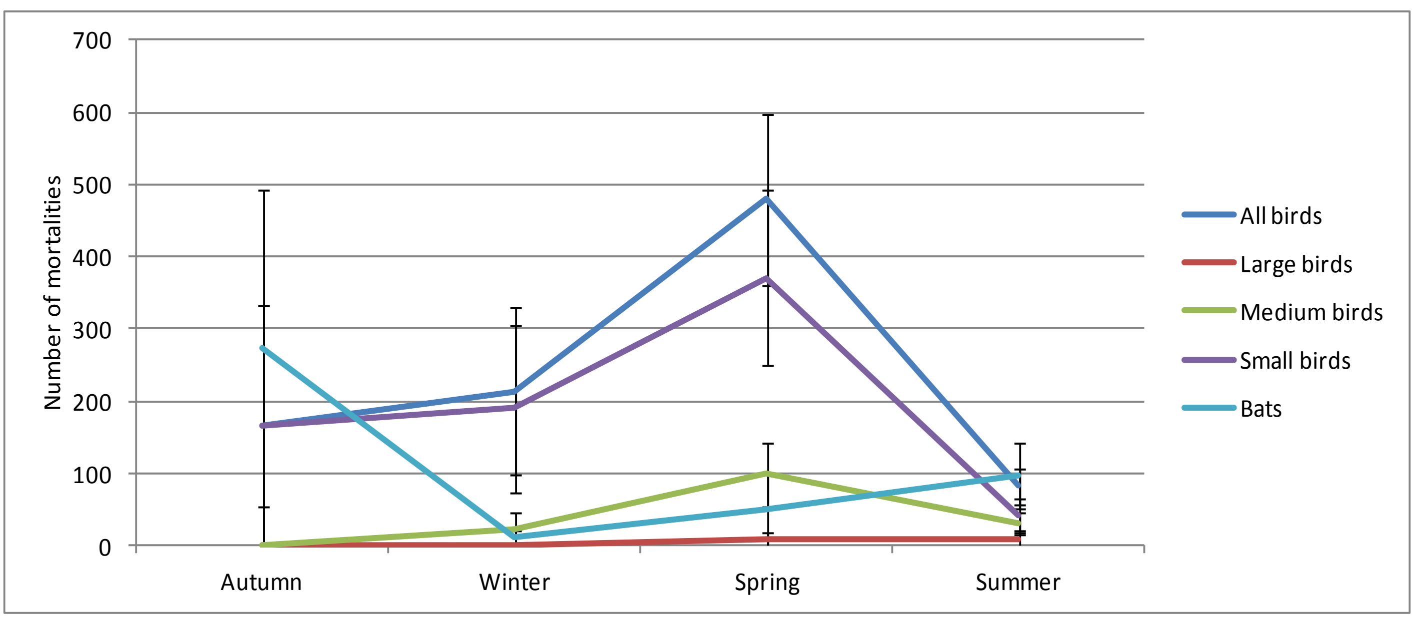


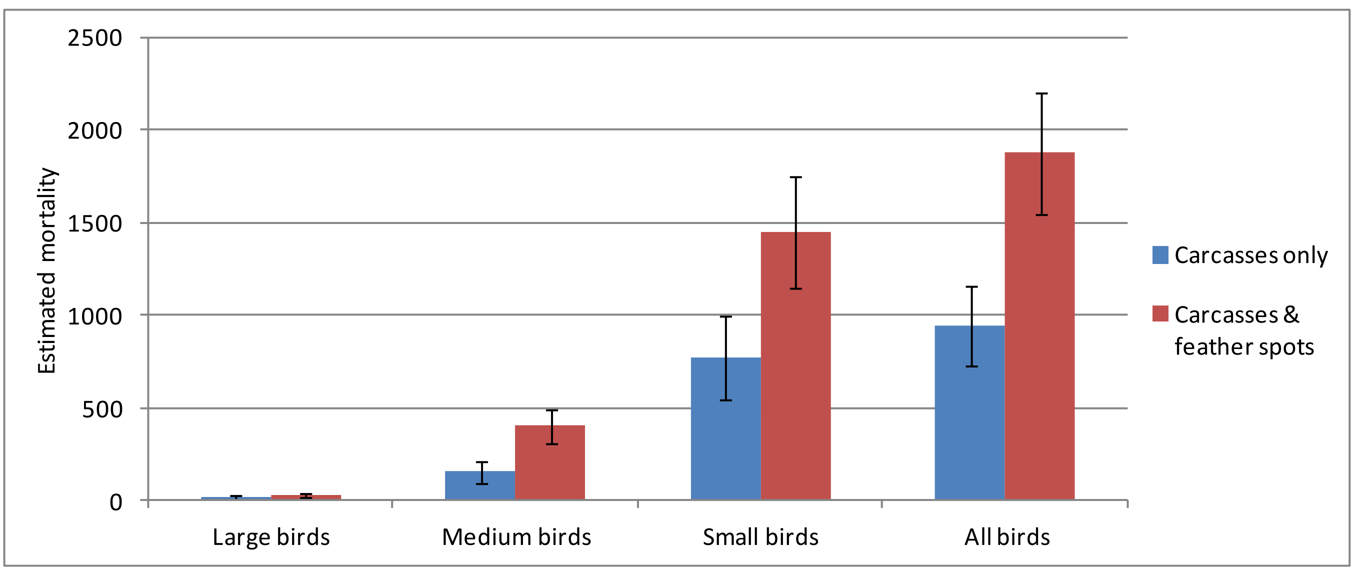
Table 11. Estimates of seasonal and annual bird and bat mortality from finds of carcasses only

Season	Group	No. of fatalities found	Mean mortality 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	1.19	0	3.73	166.13	0	522.20
	Medium birds	0	0	0	0	0	0	0
	Large birds	0	0	0	0	0	0	0
	All birds	1	1.19	0	3.73	166.13	0	522.20
	Bats	3	1.95	0	5.31	273.19	0	743.40
Winter	Small birds	4	1.35	0	3.14	189.65	0	439.60
	Medium birds	1	0.16	0	0.52	22.96	0	72.80
	Large birds	0	0	0	0	0	0	0
	All birds	5	1.51	0	3.29	212.61	0	460.60
	Bats	1	0.07	0	0.23	10.27	0	32.20
Spring	Small birds	6	2.65	0.78	4.51	370.72	109.20	631.40
	Medium birds	4	0.71	0.03	1.38	98.93	4.20	193.20
	Large birds	1	0.07	0	0.21	9.33	0	29.40
	All birds	11	3.43	1.59	5.26	478.98	222.60	736.40
	Bats	1	0.36	0	1.12	49.75	0	156.80
Summer	Small birds	3	0.30	0	0.65	42.56	0	91.00
	Medium birds	3	0.22	0	0.47	30.52	0	65.80
	Large birds	1	0.07	0	0.21	9.33	0	29.40
	All birds	7	0.59	0.22	0.96	82.41	30.80	134.40
	Bats	5	0.70	0.01	1.39	97.44	1.40	194.60
All seasons (12 months)	Small birds	14	5.50	1.99	8.99	769.32	278.60	1258.60
	Medium birds	8	1.09	0.16	2.02	152.51	22.40	282.80
	Large birds	2	0.13	0	0.33	18.67	0	46.20
	All birds	24	6.72	3.45	9.99	940.50	483.00	1398.60
	Bats	10	3.08	0	6.68	430.73	0	935.20

3.4.3 Comparisons of bird mortality estimates calculated from finds of carcasses and feather spots and finds of carcasses only

Figure 14 shows the estimated mortality of all birds and birds of different sizes calculated from finds of carcasses and feather spots and those calculated from finds of carcasses only. Estimates of overall bird mortality was significantly greater when feather spots were included in analyses compared to those calculated from finds of carcasses only (F = 5.626, d.f. = 1, p = 0.025). Mortality of medium sized birds was also significantly greater when feather spots were included in analyses (F = 5.051, d.f. = 1, p = 0.033). However, there was no significant difference between the two mortality estimates of large birds (F = 0.226, d.f. = 1, p = 0.638) and small birds (F = 3.236, d.f. = 1, p = 0.083), although the mortality estimate of small birds tended to be greater when feather spots were included in analyses.

Figure 14. Estimated mortality of birds calculated from finds of carcasses and feather spots and finds of carcasses only.



3.4.4 Estimates of native bird mortality

The mean number of native birds killed over all seasons was estimated at 3.31 ± 0.78 per turbine, equating to a total annual mortality of 464.02 ± 109.20 over the wind farm. Medium sized birds accounted for 72% of all native bird fatalities, followed by small birds (21.2%) and large birds (6.8%). Mortality of all native birds was greatest in spring when 194.59 ± 71.40 birds were estimated to have been killed over the wind farm. Mortality of native birds in summer and autumn were relatively similar, respectively estimated at 144.23 ± 53.20 and 115.86 ± 61.60 fatalities, compared to in winter when only 9.34 ± 9.34 birds were estimated to have been killed (Figure 15). Estimated mortalities of native birds of each size class in terms of the mean number killed per turbine and total number killed over the wind farm in each season is detailed in Table 12.

Figure 15. Estimated seasonal mortality of native birds over the wind farm.

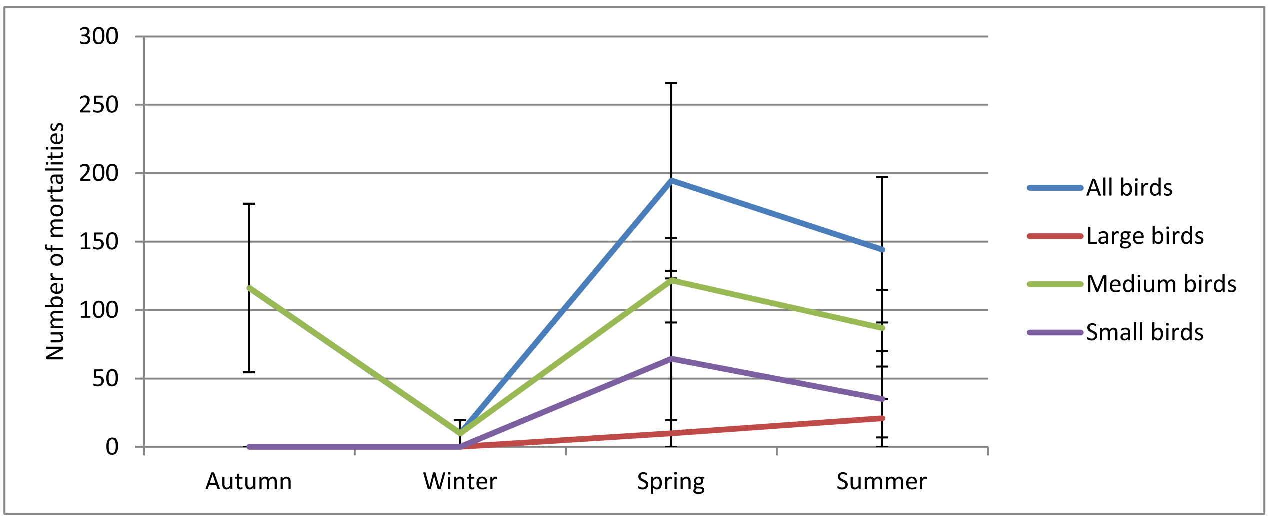


Table 12. Estimates of seasonal and annual mortality of native birds

Season	Group	No. of fatalities found	Mean mortality per turbine	95% Confidence Interval		Total mortality estimate (all turbines)	95% Confidence Interval	
				Lower limit	Upper limit		Lower limit	Upper limit
Autumn	Small birds	0	0	0	0	0	0	0
	Medium birds	3	0.83	0	1.78	115.86	0	249.20
	Large birds	0	0	0	0	0	0	0
	All birds	3	0.83	0	1.78	115.86	0	249.20
Winter	Small birds	0	0	0	0	0	0	0
	Medium birds	10	0.07	0	0.21	9.34	0	29.40
	Large birds	0	0	0	0	0	0	0
	All birds	10	0.07	0	0.21	9.34	0	29.40
Spring	Small birds	1	0.46	0	1.44	63.92	0	201.60
	Medium birds	13	0.87	0.40	1.33	121.34	56.00	186.20
	Large birds	1	0.07	0	0.21	9.39	0	29.40
	All birds	15	1.39	0.31	2.47	194.59	43.40	345.80
Summer	Small birds	3	0.25	0	0.80	35.46	0	112.00
	Medium birds	9	0.62	0.20	1.05	87.46	28.00	147.00
	Large birds	2	0.15	0	0.38	21.29	0	53.20
	All birds	14	1.03	0.21	1.85	144.23	29.40	259.00
All seasons (12 months)	Small birds	4	0.70	0	1.78	98.35	0	249.20
	Medium birds	35	2.39	0.95	3.82	333.98	133.00	534.80
	Large birds	3	0.22	0	0.47	30.63	0	65.80
	All birds	42	3.31	1.64	4.98	464.02	229.60	697.20

3.4.5 Estimates of raptor mortality

The annual mortality of raptors over the wind farm was estimated at 1.11 ± 0.28 fatalities per turbine, equating to a an overall mortality of 154.88 ± 39.20 raptors. The mortality of raptors was greatest in winter when 0.51 ± 0.23 raptors per turbine were estimated to have been killed, followed by spring (0.40 ± 0.16 fatalities / turbine) and summer ().20 ± 0.11 fatalities / turbine). No raptor fatalities were found during autumn (Figure 16). The estimated mortality of raptors in terms of the mean number killed per turbine and total number killed over the wind farm in each season is detailed in Table 13.

Figure 16. Estimated seasonal mortality of raptors over the wind farm.

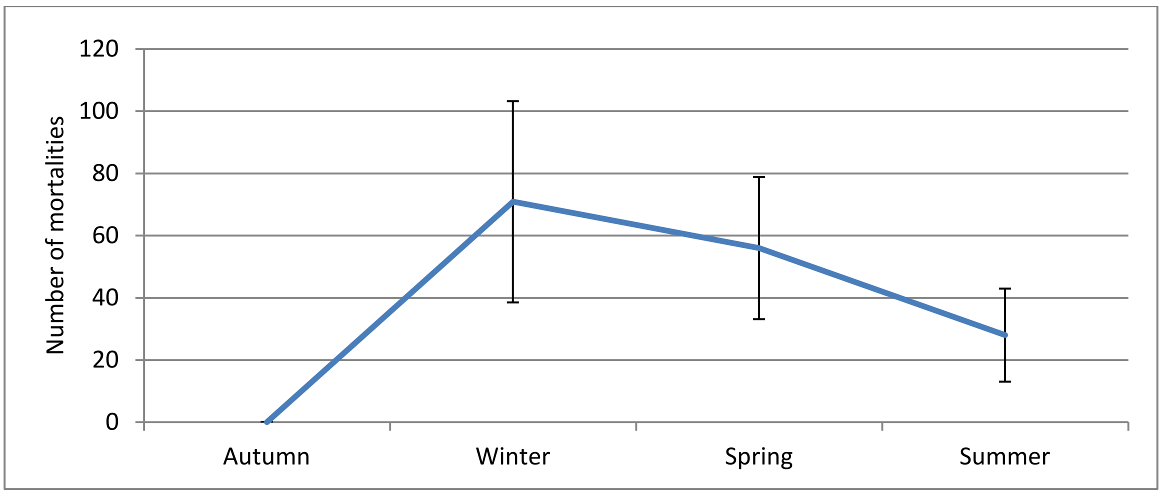


Table 13. Estimates of seasonal and annual mortality of raptors

Season	No. of fatalities found	Mean mortality per turbine	95% Confidence Interval		Total mortality estimate (all turbines)	95% Confidence Interval	
			Lower limit	Upper limit		Lower limit	Upper limit
Autumn	0	0	0	0	0	0	0
Winter	7	0.51	0.01	1.00	70.88	1.40	140.00
Spring	6	0.40	0.05	0.75	56.00	7.00	105.00
Summer	3	0.20	0	0.43	28.00	0	60.20
All Seasons (12 months)	16	1.11	0.51	1.70	154.88	71.40	238.00

3.5 Spatial distribution of bird and bat fatalities

Bird fatalities were found at 14 of the 15 turbines searched during scheduled carcass searches, with up to nine fatalities found at a single turbine. Incidental finds of 13 bird carcasses were found at an additional 12 turbines not included in the carcass search program. Bat fatalities were found at six of the 15 turbines searched over the 12 months, of which multiple mortalities were found at three of these turbines. One bat carcass was found incidentally at an additional turbine. The number of bird and bat fatalities found during scheduled carcass searches at turbines are shown in Table 14.

Table 14. Number of bird and bat fatalities found at turbines during carcass searches.

Turbine number	Bird fatalities	Bat fatalities
21	1	2
34	4	2
35	6	1
58	6	0
62	3	0
70	3	0
72	9	0
73	9	0
85	7	3
99	4	1
104	8	1
112	8	0
116	0	0
125	4	0
135	4	0

Figures 17 and 18 respectively show the spatial distribution of all bird and bat fatalities, including those found incidentally, over the 12 months from March 2014 to end of February 2015. Bird fatalities were distributed over the entire wind farm but the greatest number of multiple fatalities at single turbines typically occurred in the central and south-east areas of the wind farm (Figure 17). There does not appear to be any pattern in the spatial distribution of bat fatalities although there seems to be a slight correlation with proximity to either wetlands or native vegetation on road reserves or shelter belts within the wind farm (Figure 18).

Figure 17. Spatial distribution of bird fatalities at Macarthur Wind Farm

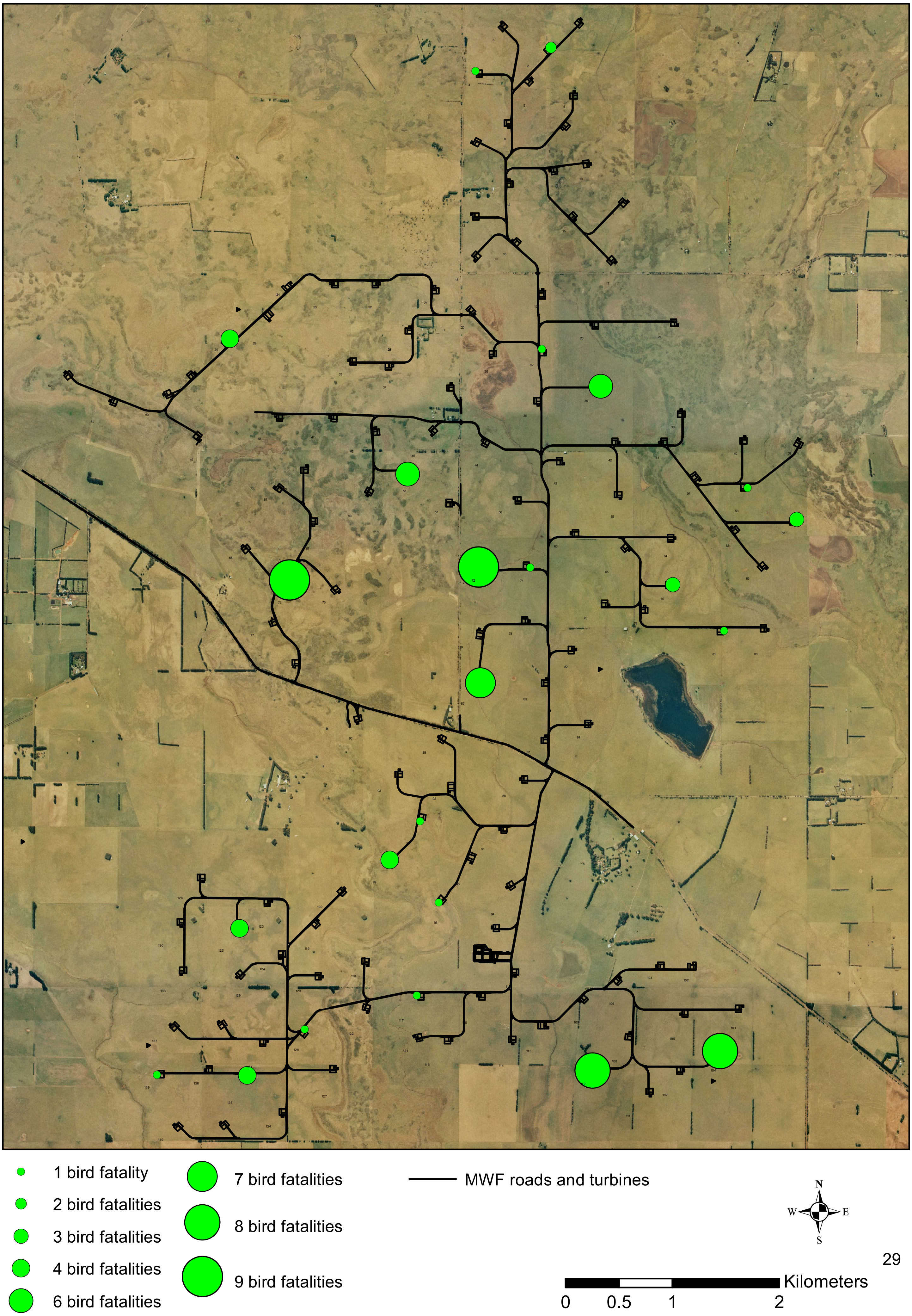
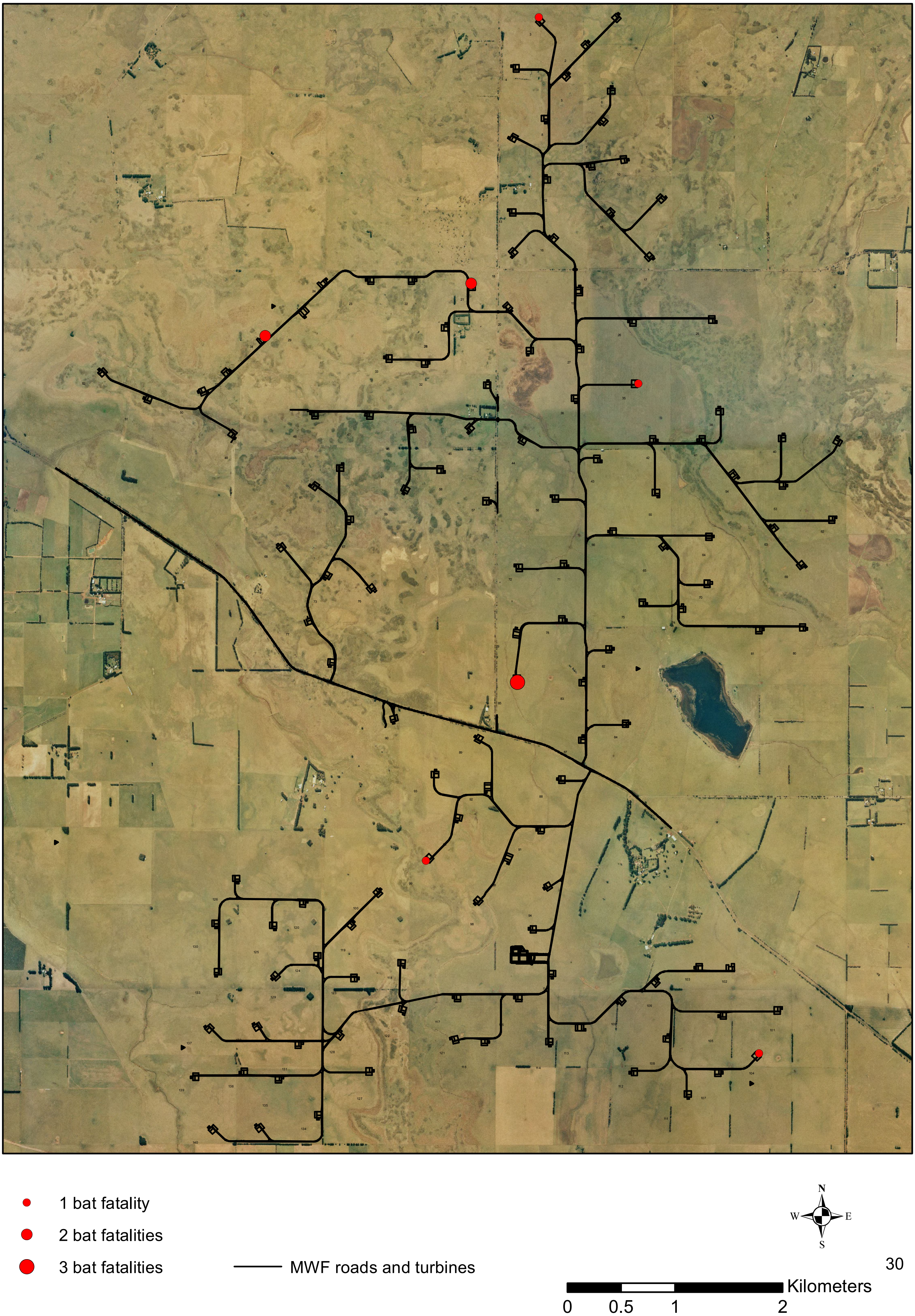


Figure 18. Spatial distribution of bat fatalities at Macarthur Wind Farm



3.6 Changes in bird and bat mortality since 2013

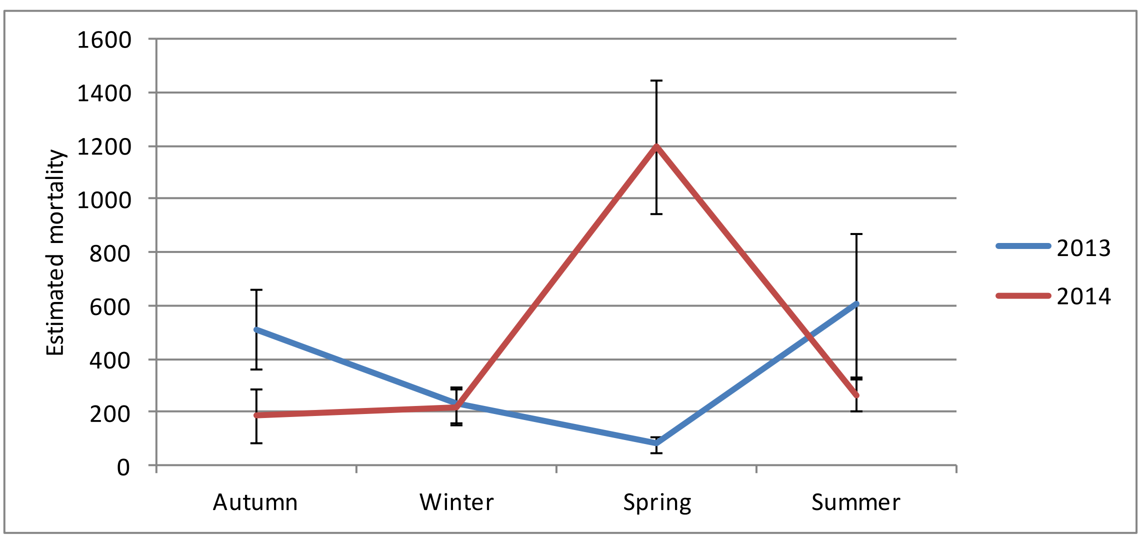
Annual mortality

Whilst the overall mortality of birds has increased slightly from a mean estimate of 10.19 ± 2.61 birds per turbine in 2013 to 13.40 ± 2.37 birds per turbine in 2014, there was no significant difference between years (t = 0.659, d.f. = 61, p = 0.512). There was also no significant difference between years in mortality of birds within each size class. The mean annual mortality of large birds per turbine averaged 0.10 ± 0.05 in 2013 compared to 0.20 ± 0.11 in 2014 (t = 0.849, d.f. = 61, p = 0.399). Mortality of medium birds decreased since 2013, respectively averaging 5.62 ± 1.28 and 2.87 ± 0.66 birds per turbine per year in 2014 (t = 1.184, d.f. = 61, p = 0.241). Annual mortality of small birds increased from a mean of 4.47 ± 1.90 birds per turbine in 2013 to 10.33 ± 2.14 birds per turbine in 2014 (t = 1.623, d.f. = 61, p = 0.110). There was also no significant difference between years in annual bat mortality (t = 1.120, d.f. = 61, p = 0.267), averaging 1.41 ± 0.65 bats per turbine in 2013 compared to 3.08 ± 1.68 bats per turbine in 2014.

Seasonal mortality

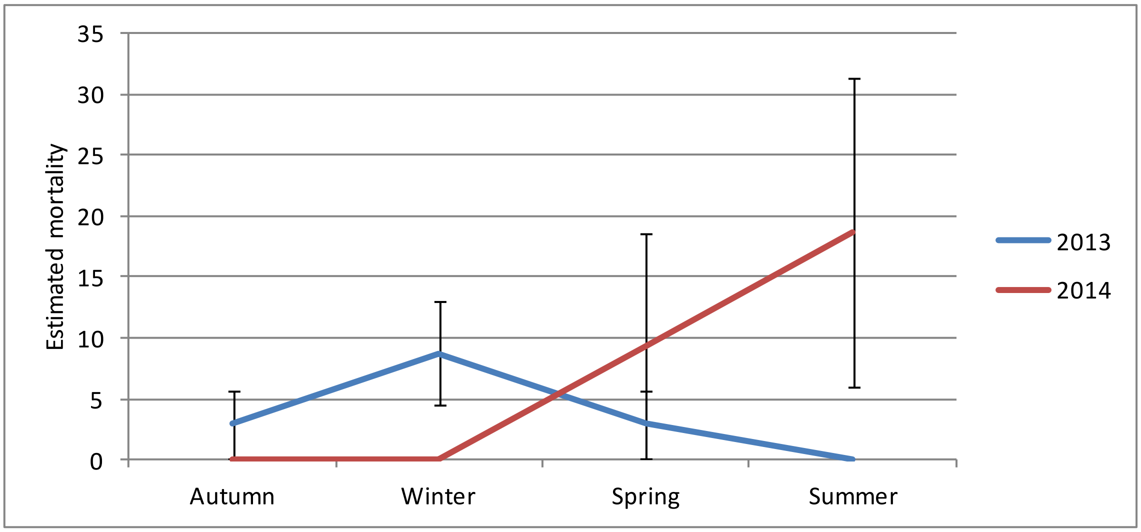
Seasonal mortality of all birds varied significantly between 2013 and 2014 (F = 5.497, d.f. = 3, p = 0.001). Figure 19 shows that the estimated mortality of all birds was lowest in spring 2013 but greatest in the following spring. Mortality of all birds in 2014 was lower in autumn and summer than in 2013 whilst that in winter was similar over both years.

Figure 19. Estimated seasonal mortality of all birds in 2013 and 2014



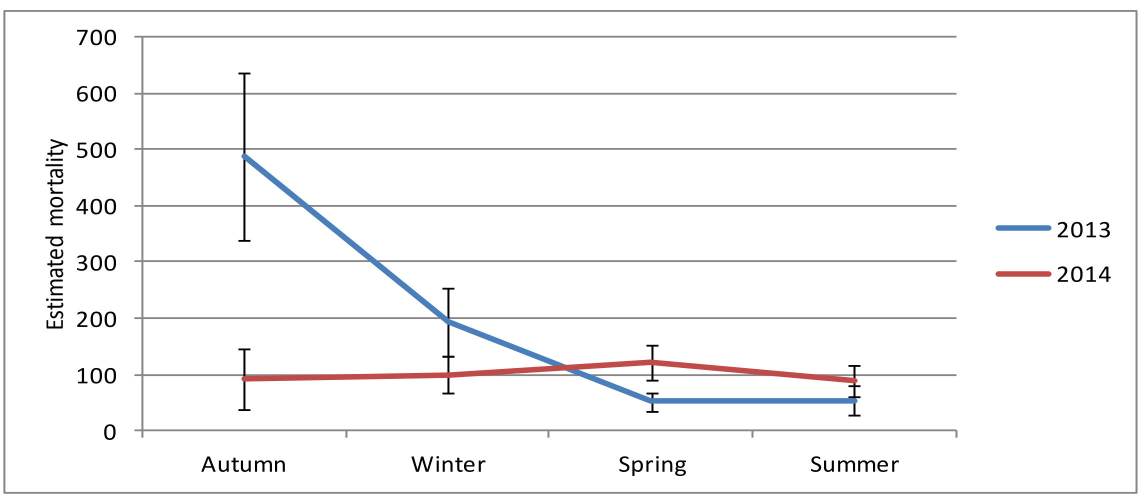
Seasonal mortality of large birds also varied significantly between years (F – 2.740, d.f. = 3, p = 0.044). In 2013, the estimated mortality of large birds was greatest during winter and lowest during summer, whilst in 2014 mortality of large birds was greatest during summer and lowest in autumn and winter when no fatalities were found (Figure 20).

Figure 20. Estimated seasonal mortality of large birds in 2013 and 2014



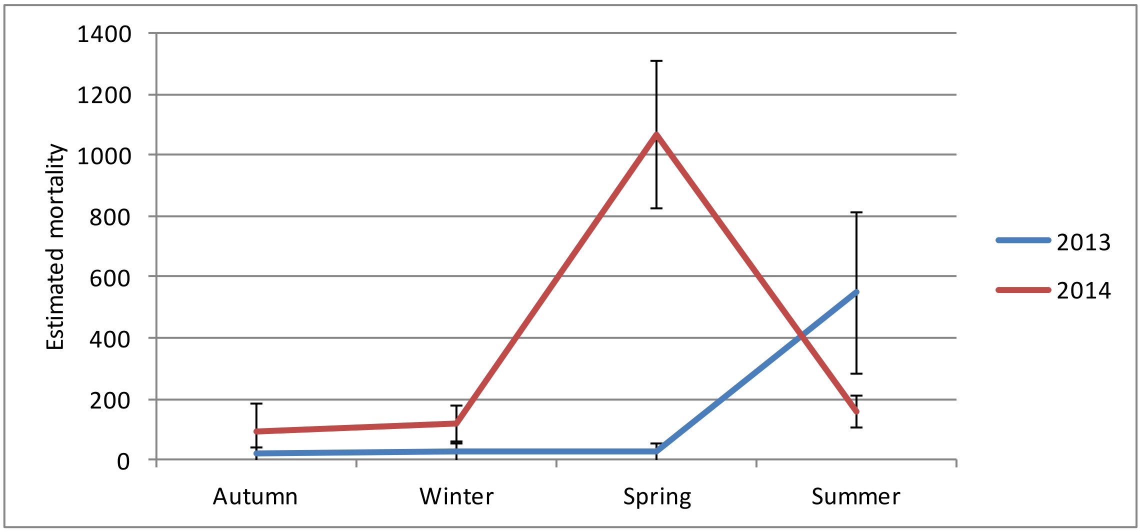
Seasonal mortality of medium sized birds varied significantly during 2013 with the greatest number of mortalities occurring during autumn and lowest during spring and summer. However during 2014, the estimated mortality of medium birds was relatively similar in all seasons (Figure 21). Despite this apparent difference between years in the estimated seasonal mortality of medium sized birds, such variation was not significant (F = 2.040, d.f. = 3, p = 0.109).

Figure 21. Estimated seasonal mortality of medium birds in 2013 and 2014



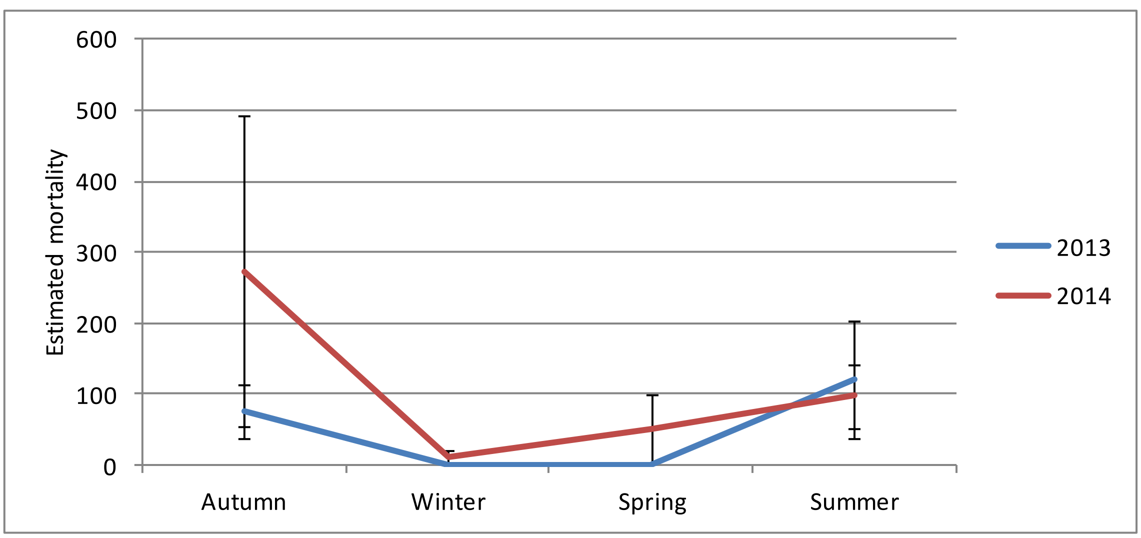
Seasonal variation in the estimated mortality of small birds differed significantly between years (F = 5.618, d.f. = 3, p = 0.001). Figure 22 shows that in 2013, mortality of small birds was significantly greater in summer than in all other seasons whereas during 2014, mortality was significantly greater in spring than in all other seasons.

Figure 22 Estimated seasonal mortality of small birds in 2013 and 2014



There was no significant difference between years in the seasonal mortality of bats (F = 0.859, d.f. = 3, p = 0.463), with most bat mortalities occurring during autumn and summer in both years (Figure 23).

Figure 23. Estimated seasonal mortality of bats in 2013 and 2014



3.7 Recommendations for further monitoring

This bat and avifauna mortality monitoring program has addressed all requirements of Condition 11b of the Planning Permit for the Macarthur Wind Farm, specifically detailing of the number and species of birds and bats struck by turbine blades including seasonal and annual estimates of mortality over the wind farm from February 2013 to 2015. During this period, additional surveys were undertaken to monitor seasonal utilisation of habitat by local bat populations (Wood 2014e, 2014g) as well as the presence, behaviour and movements of Brolga, especially breeding pairs, within the vicinity of the wind farm (Wood 2013, 2014h). Following record rainfall in September 2016, the impact of wet and dry climatic conditions on Brolgas usage of the wind farm site and close surrounds was investigated by undertaking further surveys from October to the end of the 2016 breeding season and comparing the Brolgas use of habitat to that observed in 2014 when dry climatic conditions were experienced (Wood 2017).

All monitoring programs of bird and bat mortality and studies of habitat utilisation by Brolgas and bats have been conducted at an increased survey effort than stipulated by the Bat and Avifauna Management Plan. As such, the results of these monitoring programs are expected to be accurate and reliable and no further monitoring is believed necessary.

4.0 DISCUSSION

Annual mortality of birds at the Macarthur Wind Farm was estimated at 13.40 ± 2.37 birds per turbine. When extrapolated over all turbines, this equates to a total of 1,875 ± 371 birds over the entire wind farm. Small birds accounted for the vast majority of bird mortalities (77% of mortalities) averaging 10.33 ± 2.14 birds per turbine per year compared to that of large (1.5%) and medium birds (21.5%) respectively averaging 0.20 ± 0.11 and 2.87 ± 0.66 mortalities per turbine. The Eurasian Skylark, an introduced species, was the most common bird fatality found during carcass searches, accounting for 36.8% of all fatalities found. Fatalities of Nankeen Kestrels and Australian Magpies were also relatively high, respectively accounting for 14.5% and 10.5% of all fatalities. No threatened bird species were found during carcass searches or incidentally at other turbines not included in the carcass search program.

There was little seasonal variation in the mortality of large and medium sized birds, however, the mortality of small birds was significantly higher in spring than in any other season. Such high mortality of small birds in spring was almost entirely due to fatalities of introduced species, with the Eurasian Skylark accounting for 82.4% of small bird fatalities, Common Starling (6%) and

European Gold Finch (6%). Only one native small bird fatality, the Stubble Quail, was found during spring.

Annual bat mortality was estimated at 3.08 ± 1.68 bats per turbine, equating to 431.20 ± 235.20 over all turbines. Bat fatalities mostly consisted of the White-striped Freetail Bat (80% of fatalities) but included one carcass of a Southern Bent-wing Bat, listed as Critically Endangered under the EPBC Act and the Victorian Advisory List of Threatened Vertebrate Species (DSE 2013). A carcass of a Little Red Flying Fox was also found and included in bat fatalities for the purpose of analyses. Other than this flying fox carcass, no bat fatalities were found during winter. Bat mortality was greatest in autumn and at relatively lower levels in spring and summer.

Bat mortality at the wind farm appears to be correlated with seasonal variation in bat activity, with highest mortalities occurring when bat activity is greatest. A study of bat activity at the Macarthur Wind Farm (Wood and Radford 2015) found that the activity of most species, particularly that of the White-striped Freetail Bat and Southern Bent-wing Bat, was greatest during autumn which corresponds to periods of greatest mortality from blade strike. Since the activity of bats is significantly reduced during the colder months when most species enter a state of torpor and hibernate within roosts such as tree hollows and caves, the risk of blade strike to bats is significantly reduced during this period.

During this study, two estimates of bird mortality were undertaken to compare estimates which included finds of feather spots to those which were calculated from finds of carcasses only and excluded feather spots from analyses. Mortality estimates calculated from finds of carcasses only were significantly lower for all birds than estimates which included feather spots in analyses, totalling approximately half the mortality that was calculated from finds of both carcasses and feather spots. More accurate estimates of bird mortality are obtained from analyses which include finds of feather spots in addition to carcasses as despite a larger scavenging correction factor for carcasses compared to feather spots, exclusion of feather spots from analyses assumes that such a mortality did not occur.

Additional analyses were also undertaken to examine the mortality of native birds only as well as the mortality of raptors only. The annual mortality of native birds was estimated at 3.31 ± 0.78 per turbine, equating to a total annual mortality of 464.02 ± 109.20 when extrapolated over all 140 turbines of the wind farm. The estimated mortality of native birds accounted for only 24.7% of all bird mortality. Clearly the mortality of introduced bird species, particularly the Eurasian Skylark, dramatically influenced estimates of overall bird mortality. Raptors which included Nankeen Kestrels, Brown Falcons and Wedge-tailed Eagles accounted for 33% of native bird mortalities or 22.4% of all bird mortalities, averaging 1.11 ± 0.28 fatalities per turbine, equating to an overall mortality of 154.88 ± 39.20 raptors when extrapolated over the entire wind farm. Of those bird fatalities found incidentally at turbines not included in scheduled carcass searches, 69% were raptors and included seven Wedge-tailed Eagles, a Whistling Kite and a Brown Falcon. Raptors are believed to 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). A bat and avifauna mortality monitoring program undertaken at the Yambuk Wind Farm in south-west Victoria found that raptors including Nankeen Kestrels, Swamp Harriers, Brown Falcons and Whistling Kites accounted for 70% of fatalities found during carcass searches (Wood 2010). A similar mortality monitoring program at the Cape Bridgewater Wind Farm in south-west Victoria found that Brown Falcons accounted for 50% of all fatalities found during carcass searches and Nankeen Kestrels accounted for 67% of incidental finds (Wood 2011).

During the first 12 months of mortality monitoring at the Macarthur Wind Farm, carcass searches were undertaken monthly at the same sample of turbines. It was believed that due to the high rates of carcass removal by scavengers, usually within one week, that estimates of mortality were inaccurate as most carcasses would have been removed prior to searches being undertaken and of those found, very high correction factors were applied to mortality estimates, thereby relying primarily on correction factors rather than actual mortalities. To improve the accuracy of mortality estimates, the frequency of consecutive carcass searches was increased to weekly over the following 12 month monitoring period but the sample of turbines searched was reduced from 48 to 15. It was expected that the benefits obtained by the increased accuracy of carcass searches at individual turbines would outweigh the reduced sample size. Comparisons of bird and bat mortality between 2013 and 2014 showed that there was no significant difference between years, although there was a substantial increase in the mortality of small birds since 2013 which accounted for the majority of bird mortalities. As discussed, the high mortality of small birds recorded in 2014 was due to the large number of introduced species killed, particularly Eurasian Skylarks. Mortality of large birds, on the other hand, remained at similar levels to 2013 whilst that of medium sized birds decreased. Mortality of bats increased slightly but not significantly. The apparent increased mortality of small birds and bats since 2013 may in part be due to the increased frequency of carcass searches, thereby reducing the probability that carcasses will be scavenged before searches are undertaken.

Over the two year monitoring period from March 2013 to February 2015, three fatalities of threatened species were found. These were the Black Falcon (*Falco subniger)*, listed as vulnerable under the Advisory List of Threatened Vertebrate Fauna in Victoria (DSE 2013), the Fork-tailed Swift (*Apus pacificus)*, a listed Marine and Migratory species under the EPBC Act 1999 and the Southern Bent-wing Bat (*Miniopterus schreibersii bassanii)*, listed as Critically Endangered under the Environment Protection and Biodiversity Conservation Act 1999 and threatened under the Victorian Flora and Fauna Guarantee Act 1988. Both the Black Falcon and Fork-tailed Swift have a relatively low occurrence on the wind farm site, neither of which were recorded during pre or post construction surveys of bird utilisation at the wind farm, and therefore it is unlikely that populations of these species will be significantly impacted by collision with turbines. The Southern Bent-wing Bat was recorded at moderate levels of activity on the wind farm during post-construction bat monitoring surveys using Anabat detectors (Wood 2014e, Wood and Radford 2015). However, it is believed that the risk of blade strike to this species is low due to its preference to forage amongst treed areas rather than in areas of open pastures where the wind turbines are located and its tendency to fly more frequently below rotor-swept height rather than within it. The Brolga (*Grus rubicunda*), a threatened species listed under the Victorian Flora and Fauna Guarantee Act 1988, also use the Macarthur Wind Farm during winter and spring when wetlands provide suitable habitat for foraging and nesting. No fatalities of this species resulting from blade strike have been found at the wind farm. Over a two-year monitoring study of habitat utilisation and behaviour of Brolga within the vicinity of the Macarthur Wind Farm (Wood 2013, 2014f), it was concluded that the risk of blade strike to this species is also low due to their low frequency of flights during the breeding season and observed behaviour in deliberately avoiding the rotor-swept area of turbines when flying.

5.0 REFERENCES

Barrios, L and Rodriguez, A. (2004). Behaivioural and environmental correlates of soaring-bird mortality at on-shore wind turbines. *Journal of Applied Ecology* **41:** 72-81

DSE (2013). *Advisory List of Threatened Vertebrate Fauna in Victoria*. Department of Sustainability and Environment, Victoria.

Erickson, W., Kronner, K. and Gritski, B. (2003). *Nine Canyon Wind Power Project, Avian and Bat Monitoring Report, September 2002 - August 2003*. West Inc. & Northwest Wildlife Consultants Inc.

Garvin, J.C., Jennelle, C.S., Drake, D., and Grodsky, S.M. (2011). Response of Raptors to a wind farm. *Journal of Applied Ecology* **48**: 199-209.

Hoover, S.L. and Morrison, M.L. (2005). Behaviour of Red-tailed Hawks in a wind turbine development. *Journal of Wildlife Management* **69**: 150-159.

Hull C.L. and Muir S. (2010). Search areas for monitoring bird and bat carcasses at wind farms using a Monte-Carlo model. *Australasian Journal of Environmental Management.* **17**: 77 - 87.

Kikuchi, R. (2008). Adverse impacts of wind power generation on collision behaviour of birds and anti-predator behaviour of squirrels. *Journal for Nature Conservation*. **16**: 44-55

Percival, S. (2005). Birds and wind farms: What are the real issues? *British Birds* **98**: 194-204.

Smallwood, K.S., Rugge, L., and Morrison, M.L. (2009). Influence of behaviour on bird mortality in wind energy developments. *Journal of Wildlife Management* **73**: 1082-1098.

Stewart, G.B., Pullen, A.S. and Coles, C.F. (2007). Poor evidence-base for assessment of windfarm impacts on birds. *Environmental Conservation* **34**: 1-11.

Wood, M. (2010). *Yambuk Wind Farm Bat and Avifauna Monitoring Program. March 2006 – November 2009.* Report to Pacific Hydro Pty Ltd. Australian Ecological Research Services Pty Ltd.

Wood, M. (2011). *Cape Bridgewater Wind Farm Bat and Avifauna Monitoring Program. October 2008 – November 2010.* Report to Pacific Hydro Pty Ltd. Australian Ecological Research Services Pty Ltd.

Wood, M. (2013). *Utilisation of habitat by Brolga (Grus rubicunda) within the vicinity of the Macarthur Wind Farm – 2013.*. Report to AGL Energy Limited. Australian Ecological Research Services Pty Ltd

Wood, M. (2014a). *Macarthur Wind Farm Bat and Avifauna Monitoring – March 2013 to February 2014.* Report to AGL Energy Limited. Australian Ecological Research Services Pty Ltd

Wood, M. (2014b). *Macarthur Wind Farm Searcher Efficiency and Scavenger Trials - Autumn 2014*. Report to AGL Energy Limited. Australian Ecological Research Services Pty Ltd.

Wood, M. (2014c). *Macarthur Wind Farm Searcher Efficiency and Scavenger Trials - Winter 2014*. Report to AGL Energy Limited. Australian Ecological Research Services Pty Ltd.

Wood, M. (2014d). *Macarthur Wind Farm Searcher Efficiency and Scavenger Trials - Spring 2014*. Report to AGL Energy Limited. Australian Ecological Research Services Pty Ltd.

Wood, M. (2014e). *Bat activity at the Macarthur Wind Farm – Autumn and Spring 2013*. Report to AGL Energy Limited. Australian Ecological Research Services Pty Ltd.

Wood, M. (2014f). *Utilisation of habitat by Brolga (Grus rubicunda) within the vicinity of the Macarthur Wind Farm – 2014.*. Report to AGL Energy Limited. Australian Ecological Research Services Pty Ltd

Wood, M. (2014g). *Bat activity at the Macarthur Wind Farm – Autumn and Spring 2014*. Report to AGL Energy Limited. Australian Ecological Research Services Pty Ltd.

Wood, M. (2014h). *Utilisation of habitat by Brolga (Grus rubicunda) within the vicinity of the Macarthur Wind Farm – 2014.*. Report to AGL Energy Limited. Australian Ecological Research Services Pty Ltd

Wood, M. (2015a). *Macarthur Wind Farm Searcher Efficiency and Scavenger Trials - Summer 2014/15*. Report to AGL Energy Limited. Australian Ecological Research Services Pty Ltd.

Wood, M. and Radford, E. (2015). *Bat activity at the Macarthur Wind Farm – Autumn and Spring 2014*. Report to AGL Energy Limited. Australian Ecological Research Services Pty Ltd.

Wood, M. (2017). *Utilisation of habitat by Brolga (Grus rubicunda) within the vicinity of the Macarthur Wind Farm during the breeding season of 2016.* Report to AGL Energy Limited. Australian Ecological Research Services Pty Ltd

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 2014

Turbine #	Carcass	Carcass type	Search area	Found (Yes / No)
99	Turkey	Large bird	Outer	Yes
	Skylark	Small bird	Inner	No
	Magpie	Medium bird	Inner	Yes
	Magpie	Medium bird	Outer	Yes
	Lesser Long-eared Bat	Bat	Inner	No
	Red-browed Finch	Small bird	Inner	No
	Galah	Medium bird	Inner	Yes
104	Turkey	Large bird	Inner	Yes
	Skylark	Small bird	Inner	No
	White-striped Freetail Bat	Bat	Inner	No
	Magpie	Medium bird	Outer	Yes
	Red-browed Finch	Small bird	Inner	Yes
	Galah	Medium bird	Inner	Yes
	White-striped Freetail Bat	Bat	Inner	No
135	Turkey	Large bird	Outer	Yes
	White-striped Freetail Bat	Bat	Inner	No
	White-striped Freetail Bat	Bat	Inner	No
	Magpie	Medium bird	Inner	Yes
	Red-browed Finch	Small bird	Inner	No
	Galah	Medium bird	Outer	Yes
	Skylark	Small bird	Inner	No
	Magpie	Medium bird	Inner	Yes
34	Turkey	Large bird	Outer	Yes
	White-striped Freetail Bat	Bat	Inner	Yes
	Magpie	Medium bird	Outer	Yes
	Skylark	Small bird	Inner	No
	White-striped Freetail Bat	Bat	Inner	No
	Magpie	Medium bird	Inner	Yes
35	Turkey	Large bird	Outer	Yes
	White-striped Freetail Bat	Bat	Inner	Yes
	Magpie	Medium bird	Outer	Yes
	Skylark	Small bird	Inner	Yes
	White-striped Freetail Bat	Bat	Inner	No
	Galah	Medium bird	Outer	Yes
	Red-browed Finch	Small bird	Inner	No
	Magpie	Medium bird	Inner	Yes
85	Turkey	Large bird	Outer	Yes
	Red-browed Finch	Small bird	Inner	Yes
	Magpie	Medium bird	Inner	Yes
	Galah	Medium bird	Outer	Yes
	White-striped Freetail Bat	Bat	Inner	Yes
	Skylark	Small bird	Inner	Yes
	White-striped Freetail Bat	Bat	Inner	Yes
21	Turkey	Large bird	Outer	Yes
	Galah	Medium bird	Outer	Yes
	White-striped Freetail Bat	Bat	Inner	Yes
	Red-browed Finch	Small bird	Inner	Yes
	Skylark	Small bird	Inner	No
	Magpie	Medium bird	Inner	Yes
	White-striped Freetail Bat	Bat	Inner	No

Turbine #	Carcass	Carcass type	Search area	Found (Yes / No)
58	Turkey	Large bird	Outer	Yes
	White-striped Freetail Bat	Bat	Inner	No
	Magpie	Medium bird	Outer	Yes
	Skylark	Small bird	Inner	Yes
	Magpie	Medium bird	Inner	Yes
	Lesser Long-eared Bat	Bat	Inner	No
77	Turkey	Large bird	Outer	Yes
	White-striped Freetail Bat	Bat	Inner	No
	Galah	Medium bird	Inner	Yes
	White-striped Freetail Bat	Bat	Inner	Yes
	Red-browed Finch	Small bird	Inner	Yes
	Magpie	Medium bird	Outer	Yes

Appendix 4. Results of searcher efficiency trial – Winter 2014

Turbine #	Carcass	Carcass type	Search area	Found by Alec	Found by Alistair
21	Turkey	Large bird	Outer	Yes	Yes
	Kookaburra	Medium bird	Inner	Yes	Yes
	European Gold Finch	Small bird	Inner	Yes	No
	White-striped Freetail Bat	Bat	Inner	Yes	Yes
	Magpie	Medium bird	Outer	Yes	Yes
	Mouse	Mouse	Inner	Yes	No
	Coot	Medium bird	Outer	Yes	Yes
58	Turkey	Large bird	Outer	Yes	Yes
	Magpie	Medium bird	Inner	Yes	Yes
	Coot	Medium bird	Outer	Yes	Yes
	European Gold Finch	Small bird	Inner	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	Yes	No
	Kookaburra	Medium bird	Inner	Yes	Yes
	Mouse	Mouse	Inner	No	No
73	Turkey	Large bird	Outer	Yes	Yes
	Coot	Medium bird	Inner	No	Yes
	Mouse	Mouse	Inner	No	No
	Kookaburra	Medium bird	Outer	Yes	Yes
	European Gold Finch	Small bird	Inner	No	No
	Magpie	Medium bird	Inner	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	Yes	No
62	Turkey	Large bird	Outer	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	No	Yes
	Magpie	Medium bird	Inner	Yes	Yes
	Coot	Medium bird	Outer	Yes	No
	European Gold Finch	Small bird	Inner	Yes	Yes
	Mouse	Mouse	Inner	No	No
70	Turkey	Large bird	Outer	Yes	Yes
	Mouse	Mouse	Inner	No	No
	Magpie	Medium bird	Outer	No	Yes
	Grey Fantail	Small bird	Inner	Yes	Yes
	Kookaburra	Bat	Inner	Yes	No
72	Turkey	Large bird	Outer	Yes	Yes
	Mouse	Mouse	Inner	Yes	No
	Grey Strike-thrush	Small bird	Inner	Yes	Yes
	Raven	Medium bird	Outer	Yes	No
	Skylark	Small bird	Inner	Yes	Yes
	Galah	Medium bird	Inner	Yes	Yes
112	Turkey	Large bird	Outer	Yes	Yes
	Galah	Medium bird	Outer	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	Yes	No
	Grey Strike-thrush	Small bird	Inner	Yes	Yes
	Skylark	Small bird	Inner	No	Yes
	Magpie	Medium bird	Inner	Yes	Yes

Turbine #	Carcass	Carcass type	Search area	Found by Alec	Found by Alistair
116	Turkey	Large bird	Outer	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	No	No
	Magpie	Medium bird	Outer	Yes	Yes
	Skylark	Small bird	Inner	Yes	Yes
	Raven	Medium bird	Inner	Yes	Yes
	Mouse	Mouse	Inner	No	No
125	Turkey	Large bird	Outer	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	Yes	Yes
	Galah	Medium bird	Inner	Yes	Yes
	Grey Fantail	Small bird	Inner	Yes	Yes
	Coot	Medium bird	Inner	Yes	Yes
	Magpie	Medium bird	Outer	Yes	Yes

Appendix 5. Results of searcher efficiency trial – Spring 2014

Turbine #	Carcass	Carcass type	Search area	Found by Alec	Found by Emma
21	Turkey	Large bird	Outer	Yes	Yes
	Raven	Medium bird	Outer	Yes	Yes
	Crimson Rosella	Medium bird	Inner	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	No	No
	Scrub Wren	Small bird	Inner	Yes	Yes
	Magpie	Medium bird	Inner	Yes	Yes
58	Turkey	Large bird	Outer	Yes	Yes
	Scrub Wren	Small bird	Inner	Yes	Yes
	Magpie	Medium bird	Outer	Yes	Yes
	Crimson Rosella	Medium bird	Inner	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	Yes	Yes
	Eurasian Skylark	Small bird	Inner	No	No
73	Turkey	Large bird	Outer	Yes	Yes
	Eurasian Skylark	Small bird	Inner	No	No
	Magpie	Medium bird	Inner	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	No	Yes
34	Turkey	Large bird	Outer	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	Yes	Yes
	Magpie	Medium bird	Inner	Yes	Yes
	Raven	Medium bird	Outer	Yes	Yes
	Eurasian Skylark	Small bird	Inner	No	Yes
70	Turkey	Large bird	Outer	Yes	Yes
	Eurasian Skylark	Small bird	Inner	Yes	Yes
	Magpie	Medium bird	Outer	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	Yes	Yes
	Crimson Rosella	Medium bird	Inner	Yes	Yes
	Scrub Wren	Small bird	Inner	Yes	Yes
72	Turkey	Large bird	Outer	Yes	Yes
	Starling	Small bird	Inner	Yes	Yes
	Magpie	Medium bird	Outer	Yes	Yes
	Scrub Wren	Small bird	Inner	No	Yes
	Magpie	Medium bird	Inner	Yes	Yes
104	Turkey	Large bird	Outer	Yes	Yes
	Magpie	Medium bird	Outer	Yes	Yes
	European Gold Finch	Small bird	Inner	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	Yes	Yes
	Magpie	Medium bird	Inner	Yes	Yes
	Blackbird	Small bird	Inner	Yes	Yes
116	Turkey	Large bird	Outer	Yes	Yes
	New Holland Honey-eater	Small bird	Inner	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	No	No

	Magpie	Medium bird	Outer	Yes	Yes
	Scrub Wren	Small bird	Inner	Yes	Yes
	Magpie	Medium bird	Inner	Yes	Yes

Turbine #	Carcass	Carcass type	Search area	Found by Alec	Found by Emma
125	Turkey	Large bird	Outer	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	Yes	Yes
	Raven	Medium bird	Outer	Yes	Yes
	Starling	Small bird	Inner	Yes	Yes
	Skylark	Small bird	Inner	Yes	Yes
	Magpie	Medium bird	Inner	Yes	Yes

Appendix 6. Results of searcher efficiency trial – Summer 2014/15

Turbine #	Carcass	Carcass type	Search area	Found by Alec	Found by Emma
62	Turkey	Large bird	Outer	Yes	Yes
	Eurasian Skylark	Small bird	Inner	Yes	Yes
	Crimson Rosella	Medium bird	Inner	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	Yes	Yes
	Scrub Wren	Small bird	Inner	Yes	Yes
	Magpie	Medium bird	Outer	No	Yes
35	Turkey	Large bird	Outer	Yes	Yes
	Scrub Wren	Small bird	Inner	No	Yes
	Magpie	Medium bird	Outer	Yes	Yes
	Crimson Rosella	Medium bird	Inner	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	Yes	Yes
	Eurasian Skylark	Small bird	Inner	No	No
	Eurasian Skylark	Small bird	Inner	Yes	Yes
	Raven	Medium bird	Outer	Yes	Yes
85	Turkey	Large bird	Outer	Yes	Yes
	Eurasian Skylark	Small bird	Inner	No	Yes
	Magpie	Medium bird	Outer	Yes	Yes
	Gould’s Wattled Bat	Bat	Inner	No	Yes
	Blackbird	Small bird	Inner	Yes	Yes
	Galah	Medium bird	Inner	Yes	Yes
	Raven	Medium bird	Inner	Yes	Yes
	Eurasian Skylark	Small bird	Inner	Yes	Yes
21	Turkey	Large bird	Outer	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	Yes	Yes
	Magpie	Medium bird	Inner	Yes	Yes
	Blackbird	Small bird	Inner	Yes	Yes
	Eurasian Skylark	Small bird	Inner	No	Yes
73	Turkey	Large bird	Outer	Yes	Yes
	Crimson Rosella	Medium bird	Inner	Yes	Yes
	Magpie	Medium bird	Outer	Yes	Yes
	Gould’s Wattled Bat	Bat	Inner	Yes	Yes
	Crimson Rosella	Medium bird	Inner	Yes	Yes
	Raven	Medium bird	Inner	Yes	Yes
58	Turkey	Large bird	Outer	Yes	Yes
	Starling	Small bird	Inner	Yes	Yes
	Magpie	Medium bird	Outer	Yes	Yes
	Grey Fantail	Small bird	Inner	Yes	No
	Galah	Medium bird	Inner	Yes	Yes
	Magpie	Medium bird	Outer	Yes	Yes
34	Turkey	Large bird	Outer	Yes	Yes
	Blackbird	Small bird	Inner	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	Yes	Yes
	Magpie	Medium bird	Inner	Yes	Yes
	Grey Fantail	Small bird	Inner	Yes	Yes

Turbine #	Carcass	Carcass type	Search area	Found by Alec	Found by Emma
72	Turkey	Large bird	Outer	Yes	Yes
	Starling	Small bird	Inner	Yes	Yes
	White-striped Freetail Bat	Bat	Inner	No	No
	Galah	Medium bird	Outer	Yes	Yes
	Scrub Wren	Small bird	Inner	Yes	Yes
	Magpie	Medium bird	Inner	Yes	Yes
70	Turkey	Large bird	Outer	Yes	Yes
	Gould's Wattled Bat	Bat	Inner	Yes	Yes
	Raven	Medium bird	Outer	Yes	Yes
	Starling	Small bird	Inner	Yes	Yes
	Grey Fantail	Small bird	Inner	Yes	Yes
	Crimson Rosella	Medium bird	Inner	Yes	Yes

Appendix 7. Estimates of bird and bat mortality at each turbine searched during autumn 2014.

Turbine #	Large birds	Medium birds	Small birds	Bats	All birds
21	0	0	0	23.61	0
34	0	0	10.14	2.83	10.14
35	0	0	0	0	0
58	0	4.14	0	0	4.14
62	0	0	0	0	0
70	0	0	0	0	0
72	0	0	0	0	0
73	0	4.14	0	0	4.14
85	0	1.66	0	2.83	1.66
99	0	0	0	0	0
104	0	0	0	0	0
112	0	0	0	0	0
116	0	0	0	0	0
125	0	0	0	0	0
135	0	0	0	0	0
Mean / turbine	**0.00**	**0.66**	**0.68**	**1.95**	**1.34**
Standard error	**0.00**	**0.38**	**0.68**	**1.57**	**0.73**

Appendix 8. Estimates of bird and bat mortality at each turbine searched during winter 2014.

Turbine #	Large birds	Medium birds	Small birds	Bats	All birds
21	0	0	1.63	1.1	1.63
34	0	0	2.85	0	2.85
35	0	1.1	5.69	0	6.79
58	0	1.1	0	0	1.1
62	0	1	0	0	1
70	0	1.11	0	0	1.11
72	0	3.2	0	0	3.2
73	0	1.1	0	0	1.1
85	0	0	0	0	0
99	0	0	0	0	0
104	0	1.1	0	0	1.1
112	0	0	2.85	0	2.85
116	0	0	0	0	0
125	0	1	0	0	1
135	0	0	0	0	0
Mean / turbine	**0.00**	**0.71**	**0.87**	**0.07**	**1.58**
Standard error	**0.00**	**0.23**	**0.44**	**0.07**	**0.46**

Appendix 9. Estimates of bird and bat mortality at each turbine searched during spring 2014.

Turbine #	Large birds	Medium birds	Small birds	Bats	All birds
21	0	0	0	0	0
34	0	1	6.85	5.33	7.85
35	0	1	13.7	0	14.7
58	0	2	6.85	0	8.85
62	1	0	0	0	1
70	0	0	0	0	0
72	0	1	19.57	0	20.57
73	0	1	16.42	0	17.42
85	0	2	5.75	0	7.75
99	0	2	0	0	2
104	0	2	12.32	0	14.32
112	0	0	13.7	0	13.7
116	0	0	0	0	0
125	0	0	6.57	0	6.57
135	0	1	12.95	0	13.95
Mean / turbine	**0.07**	**0.87**	**7.65**	**0.36**	**8.58**
Standard error	**0.07**	**0.22**	**1.75**	**0.36**	**1.79**

Appendix 10. Estimates of bird and bat mortality at each turbine searched during summer 2014/5.

Turbine #	Large birds	Medium birds	Small birds	Bats	All birds
21	0	0	0	0	0
34	0	0	0	0	0
35	0	0	0	2.27	0
58	0	0	1.12	0	1.12
62	0	0	1.28	0	1.28
70	0	1	1.12	0	2.12
72	0	0	2.56	0	2.56
73	1	2.12	0	0	3.12
85	0	1.12	2.56	3.69	3.68
99	1	1.12	0	2.55	2.12
104	0	2	1.12	1.93	3.12
112	0	1	4.97	0	5.97
116	0	0	0	0	0
125	0	0	2.41	0	2.41
135	0	1	0	0	1
Mean / turbine	**0.13**	**0.62**	**1.14**	**0.70**	**1.90**
Standard error	**0.09**	**0.20**	**0.37**	**0.32**	**0.44**

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

Turbine #	Large birds	Medium birds	Small birds	Bats	All birds
21	0	0	1.63	24.71	1.63
34	0	1	19.84	8.17	20.84
35	0	2.1	19.39	2.27	21.49
58	0	7.24	7.97	0	15.21
62	1	1	1.28	0	3.28
70	0	2.11	1.12	0	3.23
72	0	4.2	22.13	0	26.33
73	1	8.36	16.42	0	25.78
85	0	4.78	8.31	6.52	13.09
99	1	3.12	0	2.55	4.12
104	0	5.1	13.44	1.93	18.54
112	0	1	21.51	0	22.51
116	0	0	0	0	0
125	0	1	8.97	0	9.97
135	0	2	12.95	0	14.95
Mean / turbine	**0.20**	**2.87**	**10.33**	**3.08**	**13.40**
Standard error	**0.11**	**0.66**	**2.14**	**1.68**	**2.37**