Oaklands Hill Wind Farm

Bird and Bat Mortality Monitoring

May 2019 to May 2021

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EXECUTIVE SUMMARY

Additional bird and bat mortality monitoring at the Oaklands Hill Wind Farm was undertaken to address deficiencies noted by DELWP in the first monitoring program. Such monitoring was to focus only on the mortality of two threatened species: the Brolga and Southern Bent-wing Bat and was to be undertaken over two consecutive years. This report details the results of the mortality monitoring program from May 2019 to May 2021.

Mortality monitoring commenced in May 2019 following a clearing search four weeks earlier to remove any carcasses that had previously accumulated in the search areas. This monitoring consisted of undertaking carcass searches at a sample of 16 turbines (50% of all turbines). From May through to the end of August when bats were mostly inactive, carcass searches were conducted once every four weeks along transects spaced at 12m intervals in a search area within 115m from the turbine base, primarily to focus on detecting large birds. From the start of September to end of April when bats are usually active, the frequency and intensity of carcass searches was increased to weekly along transects spaced at 4m intervals within a smaller search area 65m from the turbine base. The outer search area from 65 to 115m from the turbine base continued to be searched once every four weeks along transects of 12m intervals.

To account for scavenging and searcher efficiency bias, trials were undertaken in each season during the first year to examine the rate of scavenging and efficiency of searchers in detecting carcasses of large birds and bats. Turkeys and mice were used as substitutes for Brolga and bats, respectively. Searcher efficiency trials were repeated when a new searcher commenced monitoring.

Over the 24 months of monitoring, 98 bird fatalities including 77 feather spots and 21 carcasses were found. Magpies and Brown Falcons were the most common fatalities. The remains of one Wedge-tailed Eagle were found in the initial clearing search but no other large bird fatalities were found during the monitoring period. As such, the annual mortality of large birds was zero in both years. 10 bat carcasses consisting of seven Gould's Wattled Bats and three White-striped Freetail Bats were found. When correction factors for scavenging rate and searcher efficiency were applied, annual mortality of bats was estimated at 0.91 ± 0.66 bats per turbine in the first year and 3.59 ± 1.15 bats per turbine in the second year and averaged 2.25 ± 0.70 per turbine per year, equating to 71.96 ± 22.4 per year over the site. Estimates of bat mortality undertaken by Symbolix Pty Ltd using modelling was calculated at 3.03 bats per turbine per year, slightly higher than that calculated using the equation developed by Erickson et al. (2003).

Bat mortality was greatest in autumn in both years. No threatened bird or bat species were found to be killed by the blades of wind turbines.

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1.0 INTRODUCTION

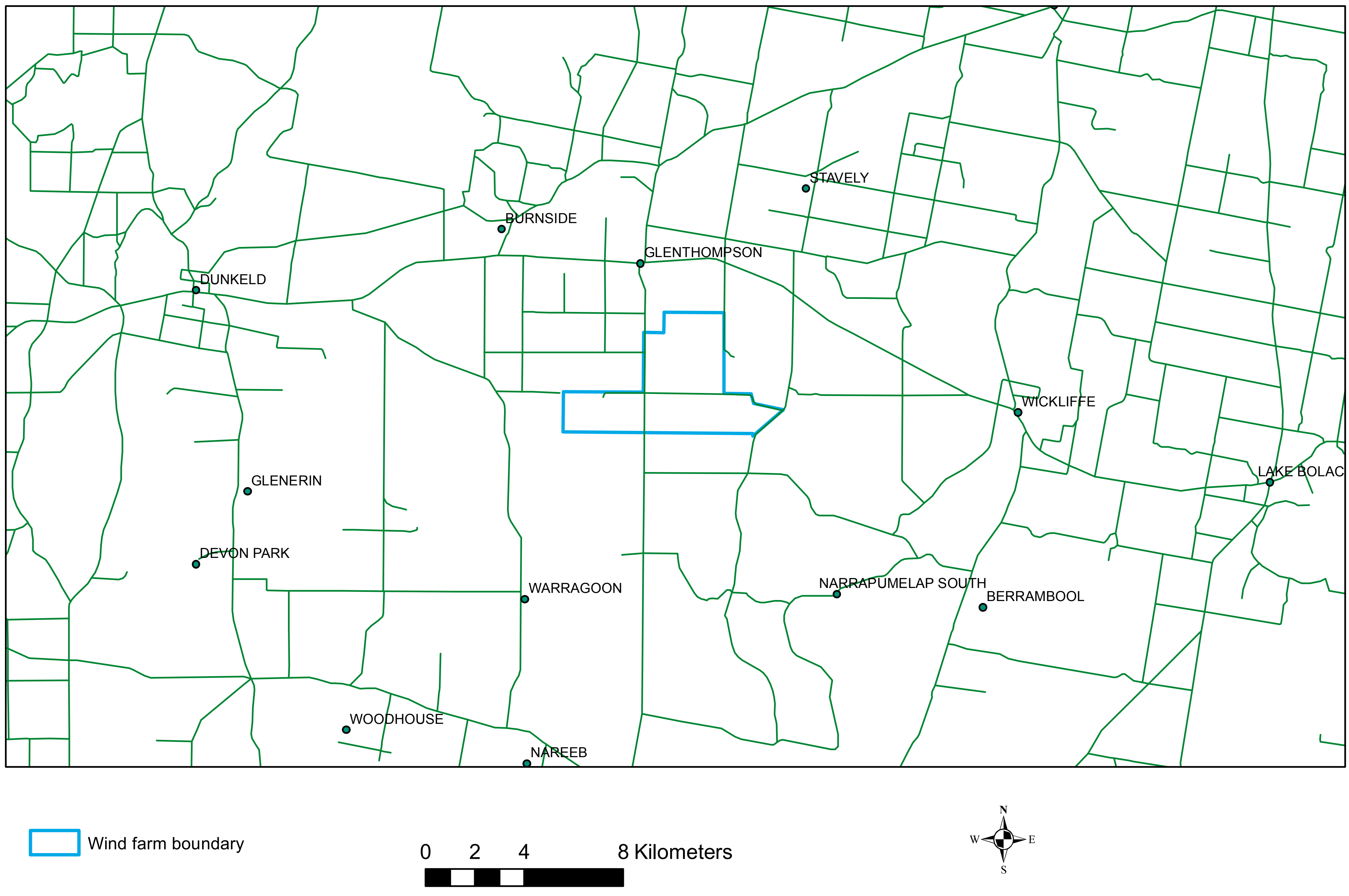
AGL Energy Limited engaged Suzlon Energy Australia Pty Ltd to build the Oaklands Hill Wind Farm. This wind farm consists of 32 wind turbines and is located on three privately owned properties on the east and west of Glenthompson-Caramut Road, approximately 8 km south of Glenthompson and covers an area of approximately 2,320 ha (Figure 1). All properties within the wind farm boundary consist primarily of pastoral land on rolling hills and valleys, elevated from the surrounding plains, and are primarily used for grazing cattle and sheep.

In accordance with the Planning Permit conditions and the endorsed Bat and Avifauna Management Plan of the Oaklands Hill 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 was initially undertaken by staff and service technicians of Suzlon Energy Australia following commissioning of the wind farm. However, DELWP noted deficiencies in the mortality monitoring undertaken and requested that an additional two years of monitoring be undertaken, but to focus on large birds and bats to specifically examine the impact on Brolga and the Southern-Bent-wing Bat.

A revised Bat and Avifauna Management Plan was prepared by Australian Ecological Research Services Pty Ltd in June 2018 (Wood 2018) primarily to outline the goals and procedures for the additional bird and bat mortality monitoring. The BAM Plan also details reporting obligations including the preparation of an annual report following the first and second years of mortality monitoring. The first 12 months of mortality monitoring was completed in May 2020 (Wood 2020).

The following report details the results of bird and bat mortality monitoring undertaken at the Oaklands Hill Windfarm over both years from May 2019 to May 2021, documenting the bird and bat fatalities recorded during this period and estimates the seasonal and annual mortality of large birds and bats attributable to collision with the blades of wind turbines.

Figure 1. Location of the Oaklands Hill 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. Estimates of mortality were only calculated for large birds and bats as were correction factors for searcher efficiency and scavenging rates.

2.1 Carcass Searches

A total of 16 turbines (50% of all turbines) were selected for carcass searches. The selection was random as far as practicable but those turbines which were located near tree plantations were avoided where possible. These plantations, mostly in the form of fenced windbreaks, would have created an obstruction to travel when walking transect lines and may have also impacted the likelihood of finding carcasses if they were to get caught in the tree canopies. Turbines selected for carcass searches are shown in Figure 2.

GIS software (Arcmap) was used to create a spatial layer of parallel transect lines within a circular search area spanning out to a radius of 115m from the turbine base at each of the selected turbines. The size of the search area was determined following recommendations by Hull and Muir (2010) relative to the height of the turbines and length of blades. 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), the search area was divided into an inner and outer search area; the inner search area was located within a 65m radius of the turbine base and the outer search area was located between 65 and 115m from the turbine base. Transect lines within the inner search area were spaced at 4m intervals for the purposes of undertaking intensive searches for bats whilst transect lines in the outer search area were spaced at 12m intervals to focus on finding carcasses of large birds such as Brolga and Wedge-tailed Eagles. Transect lines were uploaded to GPS units which were used in the field to navigate along transect lines during carcass searches. An example of the layout of transect lines within search areas is provided in Figure 3.

Carcass searches consisted of using the GPS to navigate and slowly walk along transect lines, searching the ground for carcasses of birds and bats, or remains of such, at least halfway across to the adjacent transect line. Two field workers worked together during each carcass search to comply with the occupational health and safety requirements of the wind farm site.

From the start of May to end of August, carcass searches were undertaken once every four weeks along transect lines spaced at 12m intervals throughout the entire search area within a radius of 115m from the turbine base. As bats are inactive during this time of year, intensive searches along transects spaced at 4m intervals was not necessary. Carcass searches focused purely on detecting large birds during this period and as such a less intensive search effort was sufficient.

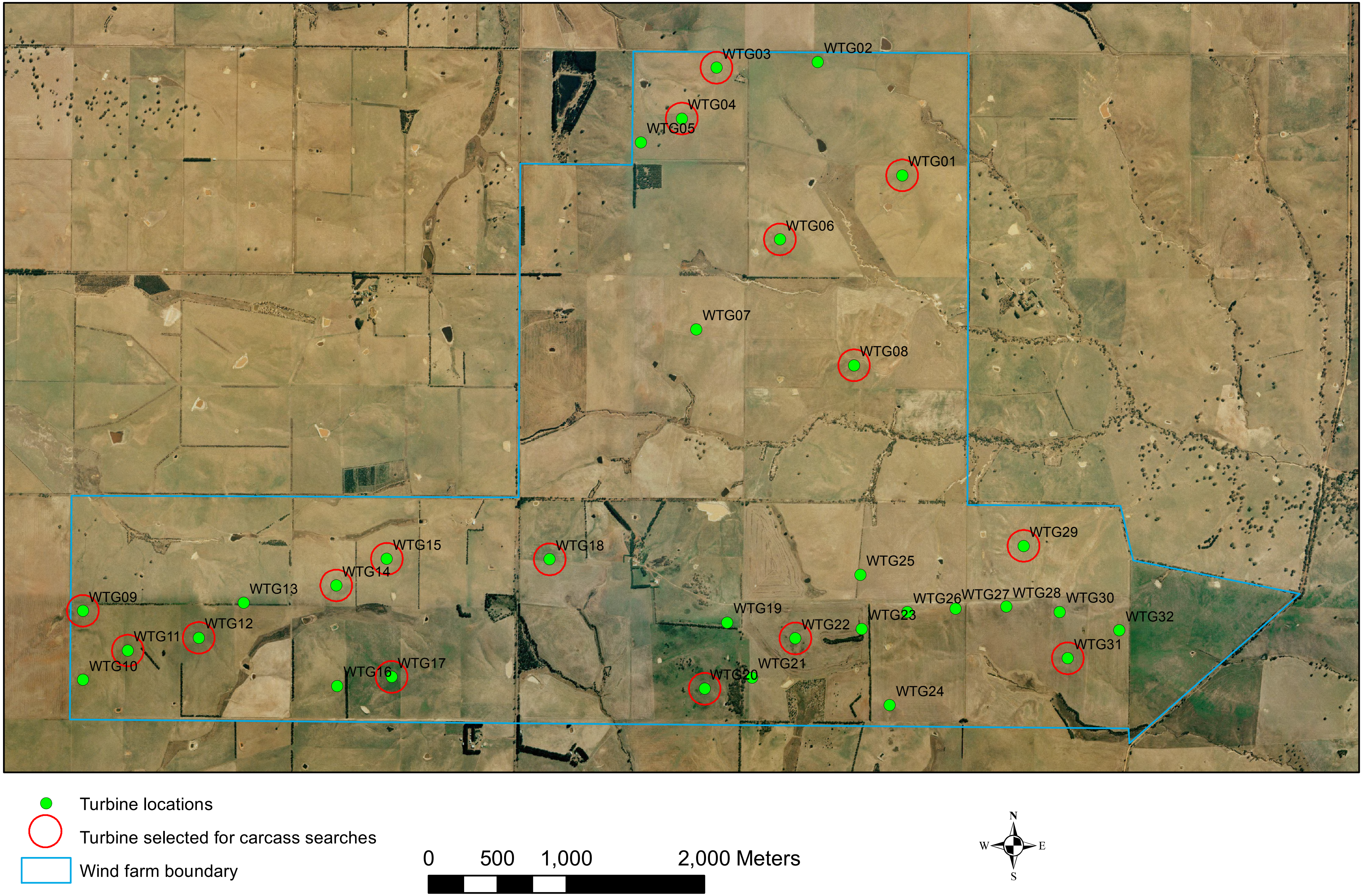
From the start of September to end of April, when bats are typically active, more intensive carcass searches were undertaken within the inner search area along transect lines spaced at 4m intervals on a weekly basis. Once every four weeks, an additional search was undertaken in the outer search area at 12m transect intervals to search for large birds that may have been killed during the previous four weeks but projected beyond 65m from the turbine.

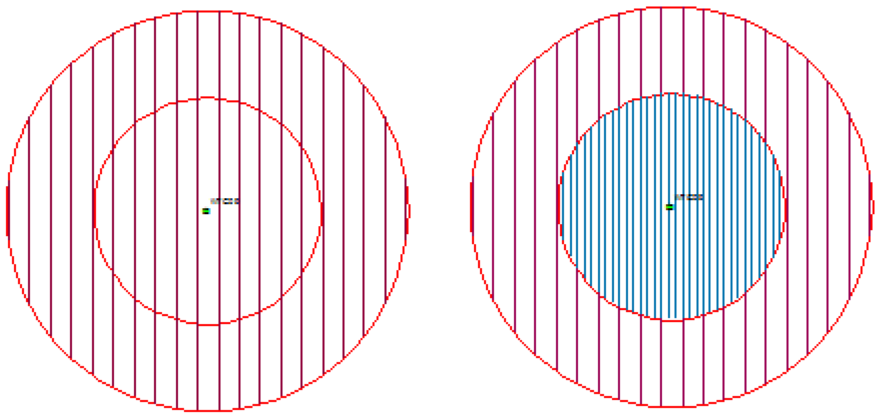
Carcass searches were undertaken according to a schedule, attempting as far as possible to maintain the same schedule and time interval between consecutive searches of the same turbine. When turbine maintenance interfered with the schedule or extreme weather conditions postponed surveys, the next turbines on the list were searched and those which had been missed were searched at the next opportunity.

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. Site information including the turbine number, date of search, presence of stock, and pasture cover and structure was recorded for all carcass searches. When a carcass or remains of a carcass, such as a feather spot or body part, was found the following details were noted: species (if identifiable), type of remains (carcass / feather spot), any signs of injury, estimated age of carcass and time since death, any evidence of scavenging, distance and bearing from turbine base, 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.

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





a) Transect intervals of 12m within the inner and outer search areas

b) Transect intervals of 4m within the inner search area and 12m in the outer search area

Figure 3. Representation of transect locations within carcass search areas

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 was 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 other than winter during the first 12 months of the monitoring period to account for variation in the visibility of carcasses in periods of different vegetation cover and rates of scavenging. Due to difficulties in obtaining Turkeys in the first winter of 2019, scavenger and searcher efficiency trials for the winter season was postponed to the following winter of 2020.

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 10 turbines scheduled for carcass searches.

As this monitoring program focused on the mortality of bats and Brolga, small and medium sized birds were not used in searcher efficiency or scavenger trials. 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. 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.

Just prior to commencement of the trial, between one and three carcasses of mice and one turkey were randomly placed within the search area of turbines to be searched that day. All mice were placed within the inner search area and the turkey was placed in 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 searchers 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 birds and bats / mice and averaged over all ten carcass searches.

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 separately for large birds and bats as well as separately for each season to account for seasonal differences in forage availability and visibility of carcasses in varying height and density of vegetation. As with the searcher efficiency trials, Slate-grey Turkeys were used as substitutes for Brolga and mice were used to substitute bats. Whole feathered turkeys were purchased fresh from a Turkey Farm in western Victoria and transported via refrigerated courier directly to the wind farm the morning after being euthanised. Mice were not used in the winter trial as it was not expected to find bats during winter due to their inactivity at this time of year.

Scavenger trials were undertaken over 30 consecutive days during approximately the middle of each season. Each trial consisted of randomly placing one turkey and one mouse within 100m of each of 10 turbines that were used for carcass searches. The same 10 turbines were used for scavenger trials in each season. The locations of carcasses were recorded on a GPS and remote cameras were setup to capture photos of scavengers feeding on the carcasses.

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

Two methods were applied to calculate mortality using the data collected from searcher efficiency trials, scavenger trials and carcass searches. The first estimate of mortality was calculated using an equation developed by Erickson *et al.* (2003) which accounts for the estimated searcher efficiency, average carcass removal time by scavengers and time interval between consecutive carcass searches. The second estimate of mortality was calculated using modelling developed by Symbolix Pty Ltd which uses a Monte-carlo simulation method. Symbolix Pty Ltd were engaged to undertake a literature review of the most recent analyses to calculate bird and bat mortality at wind farms and undertake the most accurate and appropriate analyses with the mortality data collected during this monitoring program at the Oaklands Hill Wind Farm.

Modelling to predict bat fatalities based on scavenging rate and searcher efficiencies are considered more accurate estimators of mortality at wind farms. Modelling has been used by Symbolix Pty Ltd to estimate bird and bat mortality at several wind farms in Australia over recent years and also by the Department of Environment, Land, Water and Planning (DELWP) when comparing bird and bat mortality at several wind farms in Victoria (Moloney *et al*. 2019). The analyses and estimates of mortality undertaken by Symbolix Pty Ltd are provided in Appendix 3. The following three sub-sections relate to the first method of estimating mortality developed by Erickson *et al*. (2003).

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 disappear and no longer be detectable.

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

Estimation of mortality

An estimate of mortality (m_1) for large birds 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.

Mortality was estimated separately for large birds and bats 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 for large birds and bats at each turbine was calculated by summing weekly mortality.

3.0 RESULTS

3.1 Carcass Searchers

A total of 81 carcass searches were undertaken at each of the 16 turbines from 20 May 2019 to 8 May 2021, including one clearing search just prior to the commencement of monitoring and two clearing searches each at the end of August in 2019 and 2020, equating to 1296 carcass searches over the two year period.

3.1.1 Bird fatalities

A total of 98 bird fatalities were found during carcass searches over the two years of monitoring and consisted of 77 feather spots and 21 carcasses that were either intact or partially scavenged. A total of 18 bird species were identified in fatalities although 25 feather spots could not be identified to species level (Table 1). The Magpie was the most common fatality found (35.7% of fatalities), followed by the Brown Falcon (11%). Eurasian Skylark (5%) and Australian Raven (4%).

Three other bird fatalities consisting of one Whistling Kite carcass, and feather spots of a Sulphur-crested Cockatoo and a Corella, were found incidentally near other turbines where carcass searches were not formally conducted as part of the mortality monitoring program.

No fatalities of large birds such as Brolga or any other threatened bird species were found.

3.1.2 Bat fatalities

Over the two years of monitoring, a total of 10 bat carcasses were found consisting of seven Gould's Wattled Bats and three White-striped Freetail Bats (Table 1). Neither of these species is threatened.

Table 1. Summary of bird and bat fatalities found during carcass searches from May 2019 to May 2021.

Common name	**Scientific name**	**No. carcasses**	**No. feather spots**	**Total**
Australian Magpie	*Cracticus tibicen*	6	29	35
Australian Raven	*Corvus coronoides*	2	2	4
Brown Falcon	*Falco beringora*	1	10	11
Brown Thornbill	*Acanthiza pusilla*	1	0	1
Chestnut Teal	*Anas castanea*	0	1	1
Corella spp.	*Cacatua spp*	0	2	2
Crimson Rosella	*Platycercus elegans*	1	0	1
Eurasian Skylark	*Alauda arvensis*	4	1	5
Flame Robin	*Petroica phoenicea*	1	0	1
Galah	*Eolophus roseicapilla*	0	1	1
Grey Fantail	*Rhipidura albiscapa*	1	0	1
Magpie Lark	*Grallina cyanoleuca*	0	3	3
New Holland Honeyeater	*Phylidonyris novaehollandiae*	1	0	1
Red Wattlebird	*Anthochaera carunculata*	0	1	1
Sacred Kingfisher	*Todiramphus sanctus*	1	0	1
Striated pardalote	*Pardalotus striatus*	1	1	2
Sulphur-crested Cockatoo	*Cacatua galerita*	1	0	1
Wedge-tailed Eagle	*Aquila audax*	0	1	1
Unidentified bird species		0	25	25
Avian Sub-total		**21**	**77**	**98**
Gould's Wattled Bat	*Chalinolobus gouldii*	7	0	7
White-striped Freetail Bat	*Austronomus australis*	3	0	3
Bat Sub-total		**10**	**0**	**10**

Note that five of the Brown Falcon feather spots and that of the Wedge-tailed Eagle were found during the initial clearing search prior to the commencement of carcass searches.

3.2 Searcher Efficiency Trials

Searcher efficiency trials were conducted at ten turbines in each season for each field worker. These trials were unable to commence in winter of 2019 due to a lack of turkeys available at the time and therefore commenced the following season of spring 2019. As a field worker replaced another in winter 2020, searcher efficiency trials were repeated for each season. Bats/mice were not included in the searcher efficiency trial of winter 2020 as bats are inactive at this time of year and therefore would not be expected to be found during winter carcass searches. The overall efficiency of searchers, noted as the proportion of turkeys or mice found, for each trial is shown in Table 2.

Table 2. Efficiency of searchers in detecting turkeys and mice in each trial.

Season	Searcher	Number of turkeys available	Number of mice available	Proportion of turkeys found	Proportion of mice found
Spring 2019	Emma	9	31	**1.0**	**0.81**
	James	9	31	**1.0**	**0.58**
Summer 2020	Emma	10	32	**1.0**	**0.87**
	James	10	32	**1.0**	**0.83**
Autumn 2020	Emma	10	25	**1.0**	**0.72**
	Katiesha	10	21	**1.0**	**0.71**
Winter 2020	Emma	10	N/A	**1.0**	N/A
	Michelle	10	N/A	**1.0**	N/A
Spring 2020	Emma	10	26	**1.0**	**0.81**
	Michelle	10	26	**1.0**	**0.77**
Summer 2021	Emma	10	32	**1.0**	**0.78**
	Michelle	10	32	**1.0**	**0.81**
Autumn 2021	Emma	10	28	**1.0**	**0.82**
	Michelle	10	28	**1.0**	**0.79**

3.3 Scavenger Trials

The results of the scavenger trials conducted in each season from Spring 2019 to Winter 2020 were used to calculate a correction factor for estimates of mortality. The average carcass duration for turkeys and bats/mice was calculated separately for each season. As bats are inactive during the winter months, bat/mice were not included in the scavenger trial during winter 2020. Carcass duration was defined as the average time a carcass, or any post scavenging remains, was still detectable. Carcass duration was calculated separately for carcasses only and for carcasses including any post scavenging remains, either from partly scavenged carcasses or feather spots.

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 - 10. 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 Table 3. Mice carcasses were completely removed relatively quickly particularly in autumn 2020 when all 10 mice were taken within one day. Turkey carcasses were also quickly scavenged but usually continued to be fed upon in the following days. Even after carcasses had been completely removed, feather spots often remained until the end of the trial. Only four of the 40 turkey carcasses used throughout the four trials were not detectable at the end of the trial.

Table 3. Average duration of carcass types in each season

Season	Carcass type	Average duration of carcasses only (days)	Average duration of carcasses and any post-scavenging remains (days)
Spring 2019	Turkey (n = 10)	11.3	30
	Bat/Mouse (n = 10)	2.8	2.8
Summer 2020	Turkey (n = 10)	6.5	28.1
	Bat/Mouse (n = 10)	1.9	1.9
Autumn 2020	Turkey (n = 10)	5.0	27.2
	Bat/Mouse (n = 10)	1.0	1.0
Winter 2020	Turkey (n = 10)	9.4	30

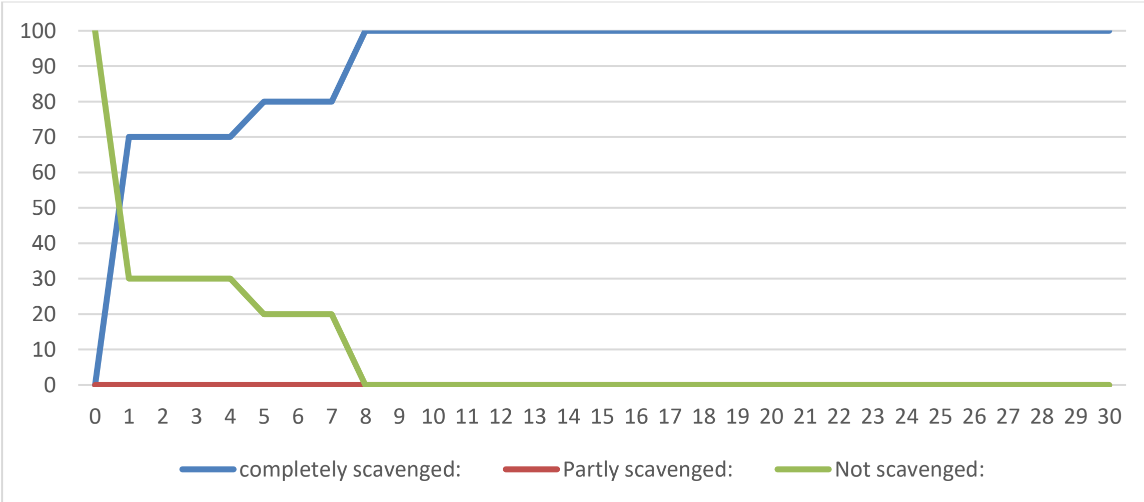


Figure 4. Rate of carcass removal for Mice – Spring 2019

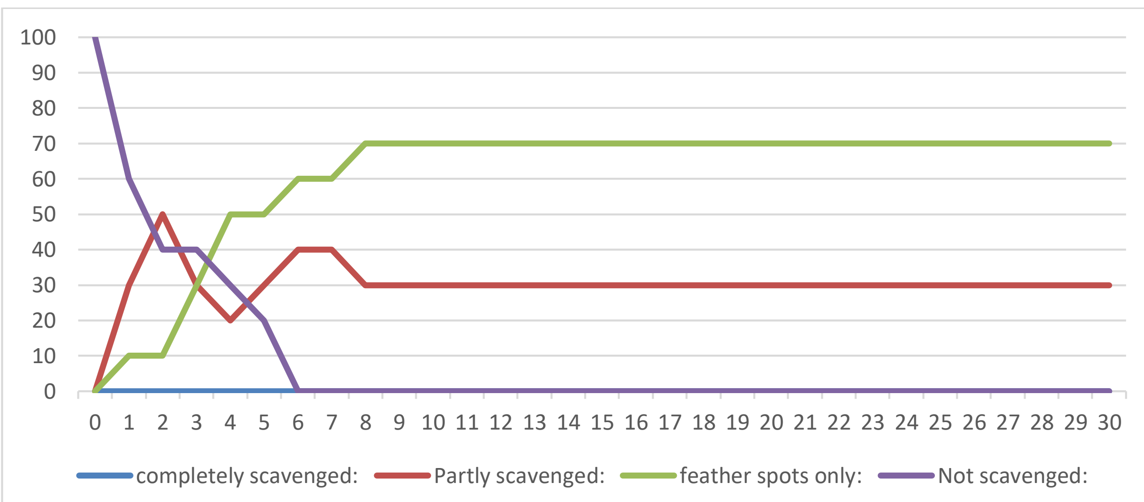


Figure 5. Rate of carcass removal for Turkeys – Spring 2019

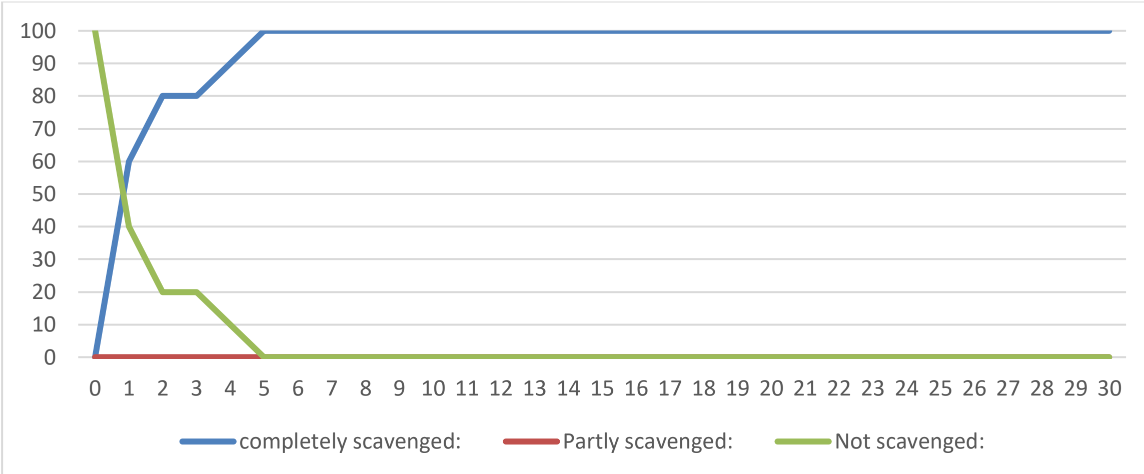


Figure 6. Rate of carcass removal for Mice – Summer 2020

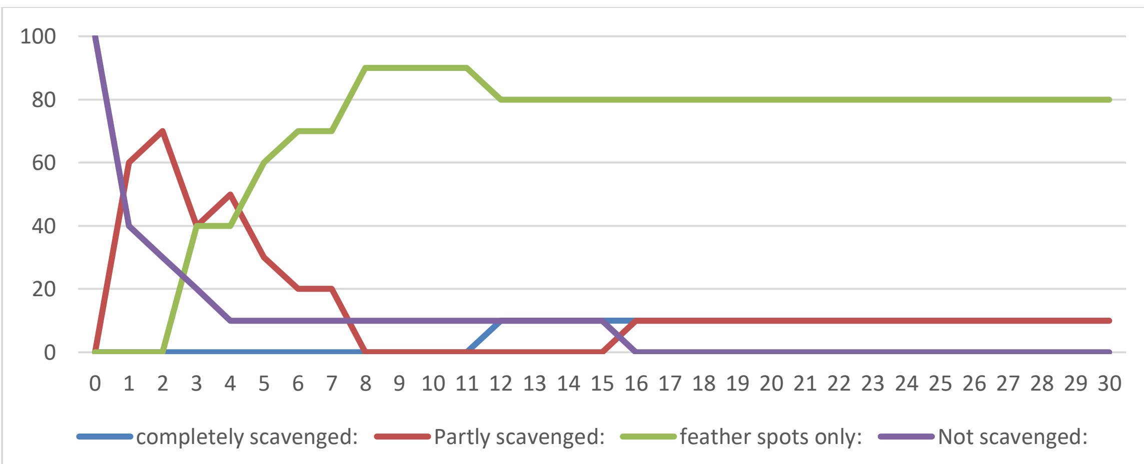


Figure 7. Rate of carcass removal for Turkeys – Summer 2020

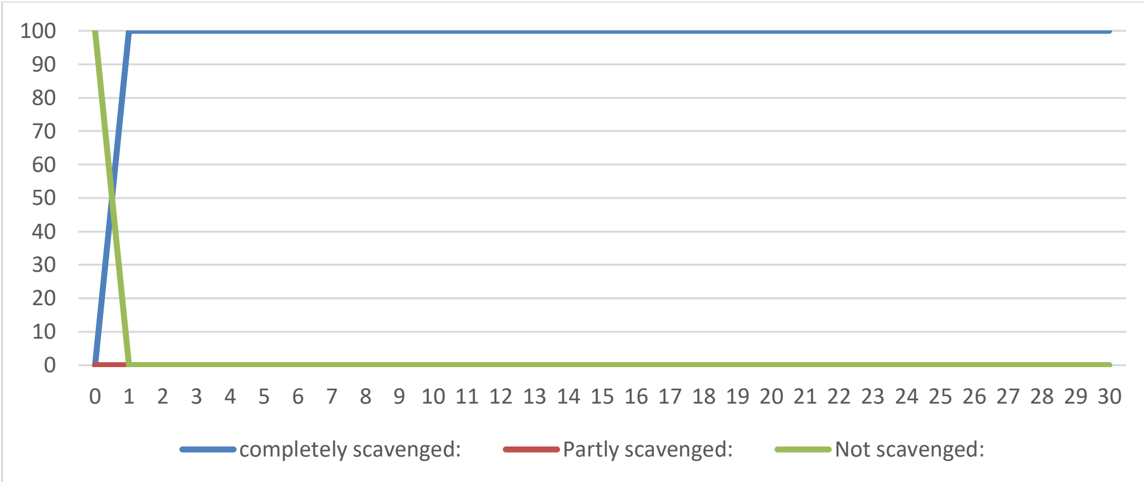


Figure 8. Rate of carcass removal for Mice – Autumn 2020

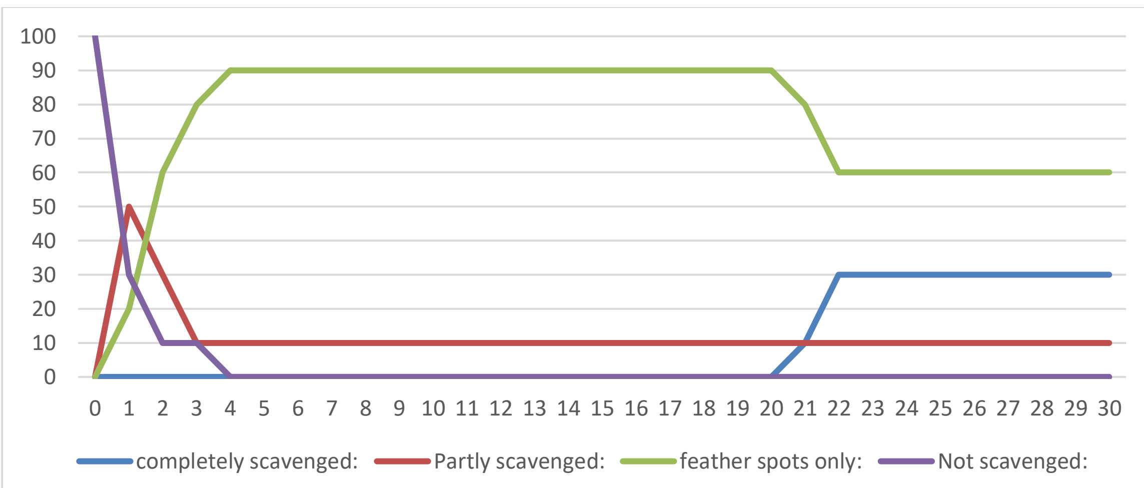


Figure 9. Rate of carcass removal for Turkeys – Autumn 2020

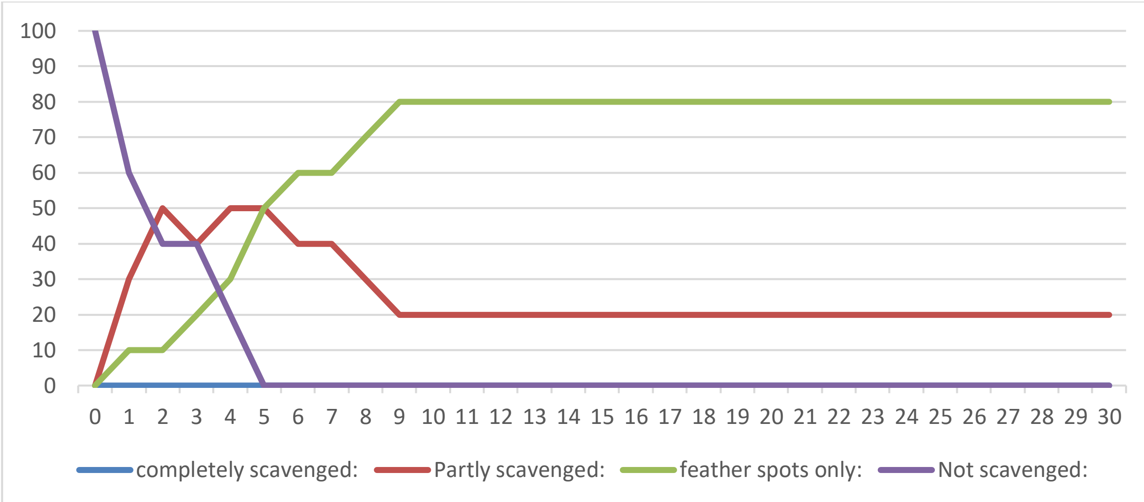


Figure 10. Rate of carcass removal for Turkeys – Winter 2020

3.4 Estimates of Mortality

Over the two year monitoring period no large birds were found and 10 bats consisting of seven Gould's Wattled Bats and three White-striped Freetail Bats were found.

3.4.1 Large bird mortality

The annual and seasonal mortality of large birds was zero.

3.4.2 Bat mortality

Annual mortality

Two bats, one Gould's Wattled Bat and one White-striped Freetail Bat, were found in the first year of monitoring and eight bats consisting of six Gould's Wattled and two White-striped Freetail bats were found in the second year.

When accounting for correction factors of searcher efficiency and scavenging rates, the mean (± S.E.) number of bats killed per turbine in the first year was estimated at 0.91 ± 0.66. When extrapolated over the entire wind farm of 32 turbines this equates to a total of 29.12 ± 21.12 bat mortalities per year over the wind farm. Annual bat mortality was greater in the second year of monitoring, averaging 3.59 ± 1.15 bats per turbine, equating to a total estimate of 114.80 ± 36.80 bats over the entire wind farm. Over both years of monitoring, the mean mortality of bats was estimated at 2.25 ± 0.70 per turbine per year, equating to 71.96 ± 22.4 over the site.

Seasonal mortality

Bat mortality was only recorded in summer and autumn and was greatest in autumn in both years. The highest bat mortality occurred in Autumn 2021 when mortality was estimated at 2.74 ± 1.04 bats per turbine. Tables 4 and 5 detail estimates of seasonal and annual bat mortality at the wind farm.

Table 4. Estimates of seasonal bat mortality at each turbine

Turbine	Winter 2019	Spring 2019	Summer 2020	Autumn 2020	Winter 2020	Spring 2020	Summer 2021	Autumn 2021	Total mortality
1	0	0	4.84	0	0	0	0	0	4.84
3	0	0	0	0	0	0	4.55	0	4.55
4	0	0	0	0	0	0	0	8.64	8.64
6	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	8.86	8.86
11	0	0	0	9.72	0	0	0	0	9.72
12	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	4.55	0	4.55
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	8.86	8.86
20	0	0	0	0	0	0	4.55	8.86	13.41
22	0	0	0	0	0	0	0	8.54	8.54
29	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
Total	0	0	4.84	9.72	0	0	13.65	43.76	71.97

Table 5. Estimates of seasonal and annual bat mortality

Season	No. of fatalities found	Adjusted mortality*	Mean mortality per turbine*	95% Confidence Interval		Total Site mortality estimate*	95% Confidence Interval	
				Lower limit	Upper limit		Lower limit	Upper limit
Winter 2019	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Spring 2019	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Summer 2020	1	4.84	0.30	0	0.95	9.60	0	30.40
Autumn 2020	1	9.72	0.61	0	1.90	19.52	0	60.80
Total Year 1	**2**	**14.56**	**0.91**	**0**	**2.32****	**29.12**	**0**	**74.24****
Winter 2020	0	0	0	0	0	0	0	0
Spring 2020	0	0	0	0	0	0	0	0
Summer 2021	3	13.64	0.85	0	1.83	27.28	0	58.56
Autumn 2021	5	43.76	2.74	0.50	4.97	87.52	16.00	159.04
Total Year 2	**8**	**57.40**	**3.59**	**1.13****	**6.05****	**114.80**	**36.16****	**193.60****
Mean per year	**5**	**35.98**	**2.25**	**0.83****	**3.67****	**71.96**	**26.56****	**117.44****

*Adjusted for searcher efficiency and scavenging bias
**Variation calculated from whole data set, not from sum of rows above.

Estimates of mortality calculated by Symbolix Pty Ltd

Mean annual bat mortality calculated by Symbolix Pty Ltd was estimated at 3.03 per turbine, equating to approximately 97 bats killed per year over the wind farm. Bat mortality was significantly higher in the second year of monitoring with mean mortality estimated at 4.56 per turbine compared to 1.49 in the first year.

Estimates of mortality calculated using Monte-carlo simulations were slightly greater than those calculated using the equation developed by Erickson *et al* (2003).

Table 6. Estimates of bat mortality undertaken by Symbolix Pty Ltd

	No. of fatalities found	Mean mortality per turbine*	95% Confidence Interval		Total Site mortality estimate*	95% Confidence Interval	
			Lower limit	Upper limit		Lower limit	Upper limit
Total Year 1	**2**	**1.49**	**0.31**	3.73	**47.76**	**10**	**119.35**
Total Year 2	**8**	4.56	**1.92**	**9.76**	**146.05**	9	**129.07**
Both years combined	**10**	**6.06**	**2.62****	**11.99****	**194**	**19****	**345****

*Adjusted for searcher efficiency and scavenging bias
**Variation calculated from whole data set, not from sum of rows above.

Source: Symbolix Pty Ltd (2021). Oaklands Hill Wind Farm Mortality Estimate – Year 2 (Appendix 3).

4.0 CONCLUSION

This bird and bat mortality monitoring program has indicated that the impact of the Oaklands Hill Wind Farm on bird and bat populations is negligible and does not appear to have caused any fatalities of the Brolga or Southern Bent-Wing Bat, nor any other threatened species. During extensive surveys for Brolga with the region (Wood 2017) and bat surveys throughout the wind farm (Wood 2011a, 2011b) no Brolga have ever been sighted on the wind farm and no Southern Bent-wing Bats have been recorded. The Oaklands Hill Wind Farm is unlikely to pose any threat to populations of these threatened species.

An estimate of mortality for small and medium birds was not calculated during this study. However, these bird fatalities consisted primarily of common farmland birds such as the Australian Magpie, Brown Falcon, Australian Raven, Magpie Lark, Corella and the introduced Eurasian Skylark. Other bird species, including threatened species, may have been killed by collision with the blades of turbines, but not detected during this monitoring program if they were killed at turbines not searched or had been completely removed by scavengers before the next carcass search.

Although most carcass searches were undertaken on a weekly basis as opposed to monthly searches that typically occur with most bird and bat mortality monitoring programs at wind farms in Victoria, the majority of bird fatalities detected (78.6%) were feather spots. This indicates that the rate of scavenging was remarkably high with most carcasses being scavenged within a week. Many bird carcasses, particularly those of smaller birds, may have been removed by scavengers without leaving any post-scavenging remains such as feather spots, resulting in mortality estimates of zero for that turbine search. Even though scavenging correction factors are used to account for scavenging bias in estimates of mortality, if no remains of a fatality is detected, the estimate of mortality is still calculated as zero. Therefore, estimates of overall mortality are most likely under-estimated even when adjusted with correction factors for scavenging rates. This would be particularly pertinent with estimates of bat mortality since most bat carcasses are completely removed by scavengers with no post-scavenging remains.

The 10 bat fatalities detected during the two-year monitoring period consisted of seven Gould's Wattled Bats and three White-striped Freetail Bats. Both species are typically the most frequently recorded bat fatalities at wind farms in Victoria due to the higher altitude in which they fly being within the rotor swept area of turbines compared to other bat species.

Annual bat mortality calculated using the equation developed by Erickson et al. (2003) was estimated at 0.91 ± 0.66 per turbine in the first year and 3.59 ± 1.15 per turbine in the second year and averaged 2.25 ± 0.70 per turbine per year. As discussed above, these mortality estimates are likely to be under-estimated due to the high scavenging rate and complete removal of carcasses prior to carcass searches being undertaken.

Modelling to predict bat fatalities based on scavenging rate and searcher efficiencies are considered more accurate estimators of mortality at wind farms. Modelling has been used by Symbolix Pty Ltd to estimate bird and bat mortality at several wind farms in Australia over recent years and also by the Department of Environment, Land, Water and Planning (DELWP) when comparing bird and bat mortality at several wind farms in Victoria (Moloney *et al*. 2019). Estimates of bat mortality undertaken by Symbolix Pty Ltd using modelling was calculated at 3.03 bats per turbine per year, slightly higher than that calculated using the equation developed by Erickson et al. (2003).

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6.0 APPENDICES

Appendix 1. Carcass search data sheet

Oaklands Hill Wind Farm - Carcass search data sheet.

Site details:

Turbine number:		Date:	
Observer:		Time:	
% cover of bare ground:		% cover of short/sparse vegetation (<10 cm):	
% cover of long/dense vegetation (>10 cm):		Stock access: (yes / no)	

Carcass details:

Carcass species (if identifiable in field)	Carcass condition (intact carcass, partly scavenged carcass, bones, feather spot)	Estimated age of carcass	Sex of carcass (M, F, ?)	Estimated no days since death	Signs of injury?	Vegetation cover within 1 m² of carcass (bare ground, short/sparse, long/dense)	Location of carcass (inner or outer search area)	Distance from turbine	Bearing from turbine	Distance to carcass when first sighted	Coordinates (GDA 94) Easting	Northing	Photo #

Appendix 2. Oaklands Hill 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. Symbolix (2021). Oaklands Hill Wind Farm Mortality estimate – Year 2.

Oaklands Hill Wind Farm Mortality Estimate - Year 2

Prepared for Australian Ecological Research Services, 30 September 2021, Ver. 1.1

This report outlines an analysis of the mortality data collected at the Oaklands Hill Wind Farm from 20/05/2019 to 08/05/2021. The analysis is broken into the three related components below:

- Searcher efficiency / detectability – estimated from trials in Spring 2019, Summer 2020, Autumn 2020, Spring 2020, Winter 2020, Summer 2021, and Autumn 2021
- Scavenger loss rates – consisting of trials in October 2019, February 2020, April 2020, and July 2020
- Mortality estimates - based on surveys at 16 turbines, from 2019-05-20 to 2021-05-08. Surveys were performed weekly from September to April and monthly from May to August (inclusive).

Mortality estimates are provided only for bats, as no large bird carcasses were found. Searcher efficiency and scavenger loss rates are estimated for bat proxies only (mouse carcasses).

The data was collected and provided by Australian Ecological Research Services and is analysed "as-is." A brief summary of the data is provided below, and the ultimate focus of this report is a discussion of the potential mortality.

Available data

The data analysed was collected, verified and provided to us from Australian Ecological Research Services[1].

Methodology overview

Mortality through collision is an ongoing environmental management issue for wind facilities. Different sites present different risk levels; consequently different sites have different monitoring requirements. In order to estimate the mortality loss at a given site (in a way that is comparable with other facilities) we must account for differences in survey effort, searcher and scavenger efficiency.

There are a number of current analytical and numerical methods suitable for estimating total

[1] AERS Oaklands Hill Bat Mortality data.xlsx

mortality from carcass counts. Analytical methods include M. M. P. Huso (2011) and F. Korner-Nievergelt et al. (2011), while Dalthorp et al. (2018) presents an numerical package that extends the analytics estimates.

A number of earlier mortality estimators exist (e.g. Erikson, M. D., and K. (2000), Smallwood (2007)), but these are rarely used today because they produce biased results or exclude some inputs. Bernardino et al. (2013) provides a good overview of these limitations.

One limitation of many analytical methods is their inability to accommodate irregular search schedules. In Australia, it is common for the time between searches to vary due to seasonal changes in effort or the use of a pulsed design in which the turbine is searched monthly with a return visit a few days later.

To allow for survey protocols with non-standard intervals, we developed a Monte-Carlo simulation method. We have used this method for annual estimates at over a dozen wind farms in Australia to date.

Monte-Carlo methods (Sawilowsky (2003), Ripley (1987)) simulate a large set of possible survey results, by simulating the actual sampling protocol and sampling from the empirical distributions for scavenge loss and searcher efficiency. In this way, we can directly sample the probability a carcass was lost before the survey, negating the need to calculate this probability analytically each time.

The analysis used survey data to estimate the average time to scavenge loss and searcher efficiency (and related confidence intervals). The algorithm then simulated different numbers of virtual mortalities. We could then estimate how many carcasses were truly in the field, given the range of searcher and scavenger efficiencies, and the survey frequency and coverage, and the true “found” details. After many simulations, we can estimate the likely range of mortalities that could have resulted in the recorded survey outcome.

This method has been benchmarked against analytical approaches (M. M. Huso (2011), Fränzi Korner-Nievergelt et al. (2011)). Its outputs are equivalent but it is able to robustly model more complex survey designs (e.g. pulsed surveys, rotating survey list).

Searcher efficiency

Searcher efficiency trials were held in Spring 2019, Summer 2020, Autumn 2020, Spring 2020, Winter 2020, Summer 2021, and Autumn 2021. “Bat proxy” (mouse) carcasses were used to determine bat searcher efficiencies and were included in six trials.

We found no evidence that searcher efficiency differed between trials or observers. Therefore, we pooled the searcher efficiency data, which decreases the variance of the estimate.

Table 1 summarises the result.

Bat detectability is 84%, with a 95% confidence interval of [80%, 87%].

Table 1: Detection efficiencies for bat proxies.

Variable	Value
Number found	405
Number placed	482
Mean detectability proportion	0.84
Detectability lower bound (95% confidence interval)	0.8
Detectability upper bound (95% confidence interval)	0.87

Scavenger efficiency

Three scavenger efficiency trials were held (October 2019, February 2020, and April 2020) that used bat proxy (mouse) carcasses. Trials ran over 30 days.

Survival analysis (Kaplan and Meier (1958)) was used to determine the average time until complete loss from scavenge. Survival analysis was required to account for the fact that we do not know the exact time of scavenge loss, only an interval in which the scavenge event happened. By performing survival analysis we can estimate the average survival percentage after a given length of time, despite these unknowns.

Like in the searcher trial analysis, we pooled the data scavenger data in order to improve the precision of our estimates.

Figure 1 shows a survival curve fitted to the survival times of the bat proxies. The survival curve (solid line) shows the estimated proportion of the set remaining at any given time. The shaded portions are the 95% confidence intervals on the estimate. For example, we see that we expect around 2% to 83% of carcasses to remain after three days with the expectation being around 13%.

Under these assumptions, the median time to total loss via scavenge is 0.6 days, with a 95% confidence window of [0.4, 1] days.

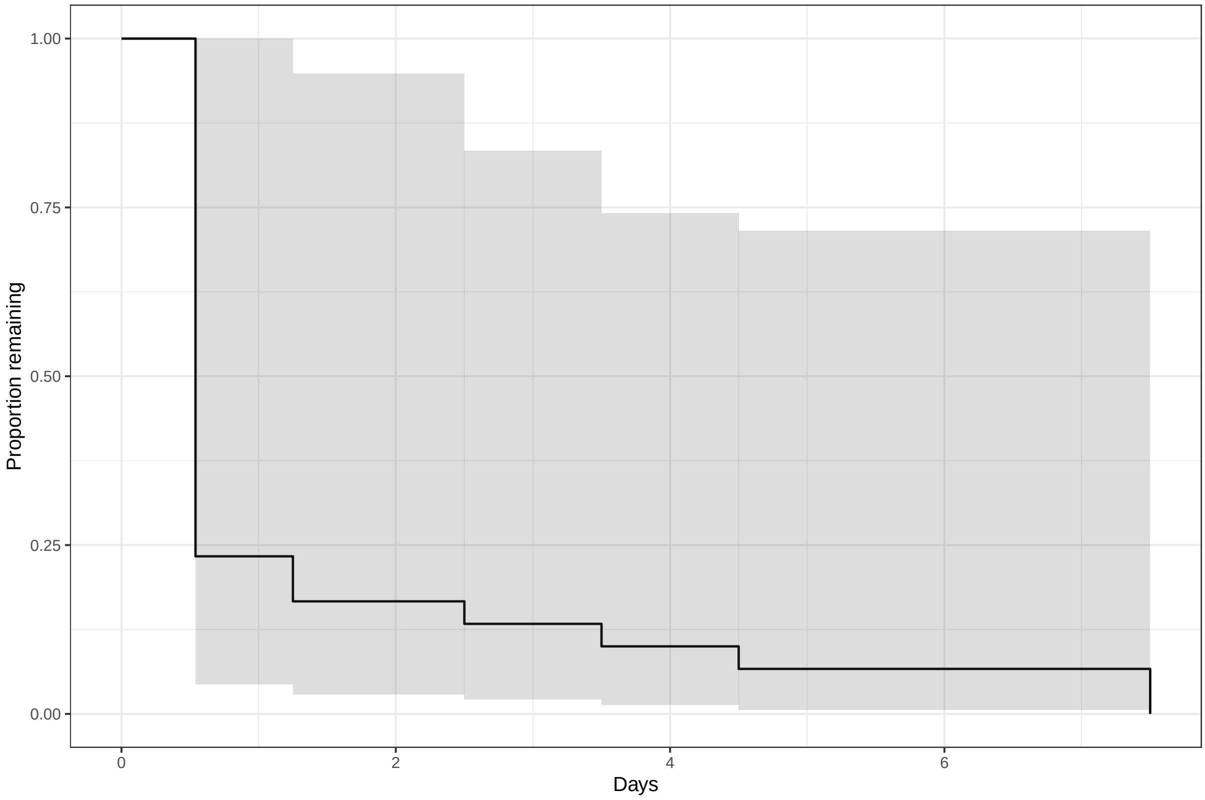

Figure 1: Survival curves for bat proxies, with 95% confidence interval shaded.

Mortality projection inputs

Carcass search data

The mortality estimate was based on a dated list of turbine surveys. The survey frequency is summarised in Table 2. Sixteen turbines were randomly selected, and were generally surveyed once each month from May to August and weekly from September to April. Turbines were surveyed out to a radius of 115 m from May to August. From September to April, turbines were surveyed out to a radius of 65 m except for once every four weeks when they were surveyed to 115 m.

Table 2: Number of surveys per month.

Date	Number of surveys
2019 Jun	16
2019 Jul	16
2019 Aug	31
2019 Sep	66
2019 Oct	72
2019 Nov	66
2019 Dec	55
2020 Jan	65
2020 Feb	68
2020 Mar	72
2020 Apr	68
2020 May	20
2020 Jun	16
2020 Jul	16
2020 Aug	36
2020 Sep	68
2020 Oct	72
2020 Nov	68
2020 Dec	60
2021 Jan	80
2021 Feb	64
2021 Mar	76
2021 Apr	68
2021 May	16

Mortality estimate - years one and two combined

Mortality estimation – methodology

With estimates for scavenge loss and searcher efficiency we then converted the number of bat carcasses detected into an estimate of overall mortality at Oaklands Hill Wind Farm from 20/05/2019 to 08/05/2021 (we allow for collisions to occur up from the time of the first clearing search).

The mortality estimation is done via Monte-Carlo simulation. We used 25000 simulations with the survey design simulated each time. Random numbers of virtual mortalities were simulated, along with the scavenge time and searcher efficiency (based on the measured confidence intervals). The proportion of virtual carcasses that were "found" was recorded for each simulation. Finally, those trials that had the same outcome as the reported survey detections were collated, and the initial conditions (i.e. how many true losses there were) reported on.

The complete set of model assumptions are listed below.

- There were 32 turbines on site.
- Search frequency for each turbine was taken from a list of actual survey dates (see Table 2 for a summary).
- Mortalities were allowed to occur from the time of the first sweep survey (20/05/2019) and until the final surveyed date (08/05/2021).
- Bats are on-site only between September and April (inclusive).
- Finds are random and independent, and not clustered with other finds.
- There was equal chance of any turbine individually being involved in a collision / mortality.
- We assumed a log-normal scavenge shape.
- We took scavenge loss and search efficiency rates as outlined above.
- 16 turbines were selected at random to be surveyed, and were searched out to a 115 metre radius from May to August and to either a 65 or 115 metre radius from September to April. We estimated the "coverage factor" for the survey – i.e. the total fall zone surveyed for birds and bats (using estimates from Hull and Muir (2010)). We assumed that the coverage factor was 100% for bats.

Mortality projection results

After running the simulation we investigated the distribution of mortalities that could have resulted in the actual numbers found during the surveys. The breakdown of found carcasses per species are summarised in Table 3.

Table 3: Carcasses found during formal surveys over two years.

Species	Bat
Goulds Wattle Bat	7
White Striped Free-tail Bat	3

Bat mortality estimate – results

During the two years of surveys a total of 10 bats were found during formal surveys (Table 3). The resulting estimate of total mortality, accounting for searcher efficiency, scavenge rate, search area and timing of surveys is an expectation (mean) of 194 and a median of 178 bats lost on site over the twenty-four months.

Table 4 and Figure 2 display the percentiles of the distribution, to show the confidence interval in this average.

The estimate of mortality per turbine over the twenty-four months is a mean of 6.06 and a median of 5.56, with a 95% confidence window of [2.62, 11.99].

Based on the detected carcasses and measured detectability and scavenge rate, we expect that there was a total site loss of around 194 bats over the survey period, and are 95% confident that fewer than 345 individuals were lost.

Table 4: Percentiles of estimated total bat losses over the two years of surveys.

0%	50% (median)	90%	95%	99%	99.9%
48	178	304	345	446	542

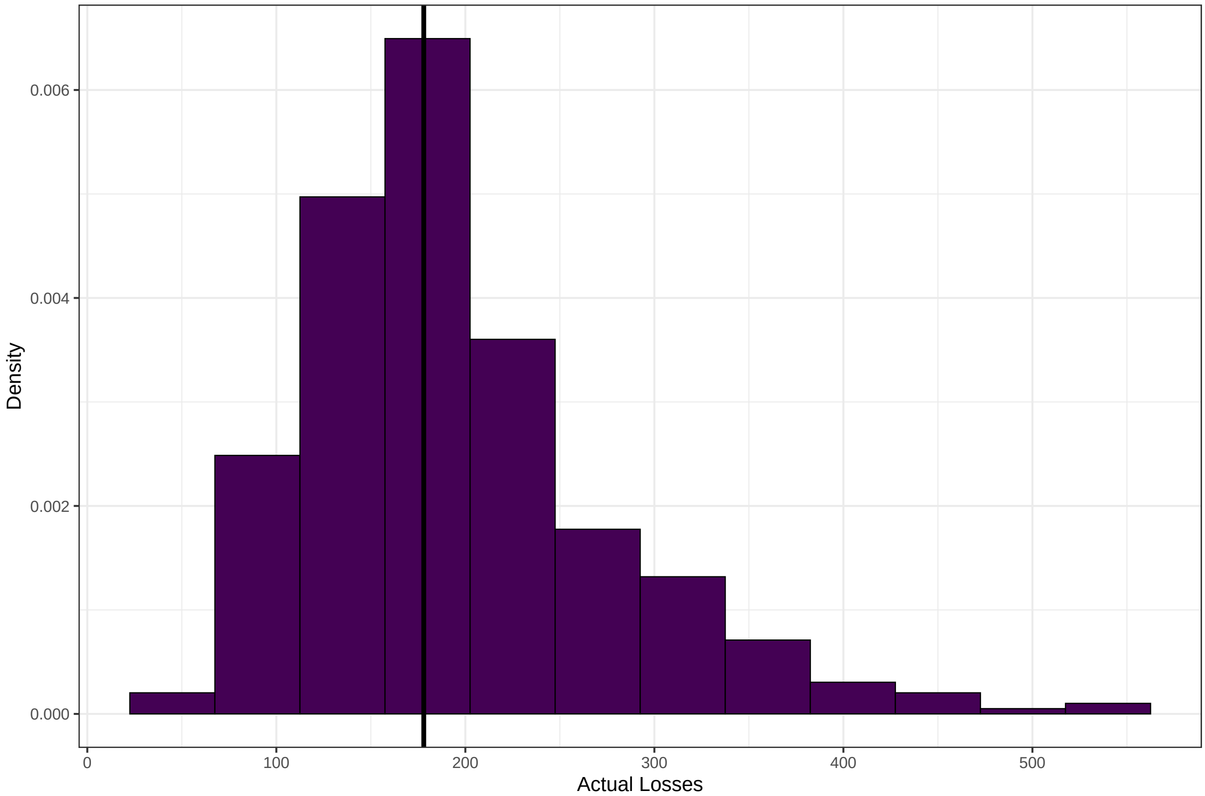

Figure 2: Histogram of the total losses distribution (bats), given 10 were detected on-site. The black solid line shows the median.

Comparison of year one and year two results

Bat results

During the first year of surveys (20/05/2019 to 22/05/2020) a total of 2 bats were found during formal surveys. The resulting estimate of total mortality is an expectation (mean) of 47.76 bats over the survey period, with a 95% confidence interval of [10, 119.35].

The estimate of mortality per turbine in the first year is a mean of 1.49 and a median of 1.31, with a 95% confidence window of [0.31, 3.73].

In comparison, in the second year of surveys a total of 8 bats were found during formal surveys. The resulting estimate of total mortality is an expectation of 146.05 bats over the survey period, with a 95% confidence interval of [9, 129.7].

The estimate of mortality per turbine in the second year is a mean of 4.56 and a median of 4.23, with a 95% confidence window of [1.92, 9.76].

Statistical testing (using the Kolmogorov-Smirnov test) was used to determine if there was a significant difference between the modelled distribution of mortalities in year one and year two.

When considering all bat mortalities, we find the distribution of the first year to be shifted left compared to the distribution of year two mortalities (the test statistic $D = 0.79$ is greater than the critical value D* = 0.35 at the 0.05 significance level).

Assuming all model assumptions hold, this would imply that the true total number of bat losses in year two was significantly higher than the number of losses in year one.

Concluding remarks

In evaluating the potential impact, it is important to remember that all mortality estimators have an inherent assumption that there is an unlimited supply of carcasses to be found. In particular, we did not apply an upper limit on the number of bats that could be onsite. The ecological feasibility of this assumption should be accounted for if using these results to comment on overall ecological impact.

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