Report 235

Post Construction Bird and Bat Monitoring Results

Year 3: July 2020 to June 2021

Yaloak South Wind Farm, Victoria

Prepared by
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for

Pacific Hydro Pty Ltd.

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SUMMARY

Introduction

Elmoby Ecology was commissioned by Pacific Hydro to undertake post construction bird and bat monitoring at the Yaloak South Wind Farm near Ballan, Victoria. The purpose of this report is to summarise the findings of the third-year of the post construction monitoring program (July 2020 – June 2021).

Methods

The methods for the following tasks undertaken in accordance with the approved BAM plan are provided in Section 2 below:

- Carcass persistence (section 2.2)
- Observer efficiency (section 2.3)
- Post construction carcass searches (section 2.4)

Data Analysis

Statistical analysis for the year three monitoring data was undertaken by Symbolix Pty Ltd. The mortality estimation is done via Monte-Carlo simulations which provides a comparable mortality estimator for complex survey designs.

Results

Searcher Efficiency

There was no measurable difference between the detection of birds and bats, nor between different dog/handler teams, therefore a single estimate of 91% with a confidence interval of [86%, 95%] was applied.

Carcass Persistence

There was evidence of differences between the scavenging rate of bats, wedge-tailed eagles and other birds and therefore different estimators are applied to account for this. There was also evidence of differences between seasons and this variability is captured within the standard error. Thus, the mean times to total loss due to scavenging are:

- Bats is 2.2 days with a 95% confidence it is between [1.5, 3.2] days.
- Birds (not including eagles) is 2.8 days with a 95% confidence it is between [2, 4] days.
- Eagles is 260 days with a 95% confidence it is between [119, 567] days.

Mortality Detection Surveys

During the third year of surveys a total of 45 finds were recorded during formal surveys, 33 bats, 8 birds and 4 wedge-tailed eagles. One additional bird, a nankeen kestrel, was found incidentally outside of the 60m survey area. A single white throated needle tail (*Hirundapus caudacutus*) was found in February 2021 during routine surveys and is listed under the EPBC and FFG Acts. All other species found are considered secure in their range.

On average we estimate the number of bats impacted during the period of this report was 186 with a 95% confidence that fewer than 259 individuals were lost. During the same period, the average impact estimate for birds is 55 with a 95% confidence that fewer than 89 individuals were lost. We estimate the total site loss for wedge-tailed eagles is 5 and are 95% confident that fewer than 7 were impacted.

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Document Information

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Contents

1 INTRODUCTION

1.1 Background

The purpose of this report is to summarise the findings of the three years of post construction bird and bat monitoring at the Yaloak South Wind Farm in accordance with the approved Bat and Avifauna Management Plan (BAMP). This plan was developed by Biosis Pty Ltd in accordance with Conditions 19 and 20 of Planning Permit PA2010002-2 for Yaloak South Wind Farm issued under the Moorabool Planning Scheme (Permit No: P2010002), as amended on 18 January 2019 by Order of the Victorian Civil and Administrative Tribunal (VCAT Reference No. P1333/2018 issued 4 January 2019). The BAMP was originally approved on 16 September 2015 and was revised in line with the amended permit conditions. The revised BAMP was endorsed by Moorabool Shire Council, in consultation with the Department of Environment, Land, Water and Planning (DELWP), on 15 May 2019.

Collection and use of specimens were conducted under the *Wildlife Act 1975* Research Permit number 10008753 which allows for the collection and storage of dead birds of bats found within the wind farm site and along state roadsides for the purpose of scavenger and searcher efficiency trials.

1.2 Scope and Objective

As outlined in the Bat and Avifauna Management Plan, the primary scope of the bird and bat monitoring program is to:

> *To ensure operations of the wind farm do not result in net significant or lasting impacts on the viability or conservation status of populations of wedge-tailed eagles, Bent-wing Bats or other listed threatened or migratory species.*

1.3 Study Area

The study area is located an hour west of Melbourne, approximately 15km south of Ballan off Glenmore Road. The project has been built in the southern section of the Yaloak Estate overlooking the Parwan Valley. The project site is predominantly cleared agricultural land used for cropping and livestock grazing. Each turbine is included and surveyed within the study.

Figure 1: Location of turbines for Yaloak South Wind Farm. Image courtesy of Google Maps

2 METHODS

2.1 Data Analysis Overview

Quantifying bird and bat mortality from turbine collision is an ongoing management issue for wind energy facilities and different sites present different risks. Different monitoring requirements apply across Victoria which means that data analysis must account for differences in survey effort, survey detection success and scavenger efficiency. Data analysis was undertaken by Symbolix Pty Ltd using Monte-Carlo simulations, which account for differences in survey effort.

2.2 Carcass Persistence Trials

Persistence trials were undertaken in years 1 and 3, to determine the rate at which carcasses persist within the survey area. The primary method of removal of carcasses is scavenging by foxes, raptors, magpies and crows. Quantifying the rate of removal by scavengers is essential to understand how many carcasses are available for detection by observers and to provide correction factors for subsequent impact estimates.

Eight carcass persistence trials were conducted over the three year monitoring period, four in year 1[*] and a further four in year 3, using a collective total of 170 carcasses, although some data was lost due to equipment failures and the interference of cows dislodging cameras, giving a final total number used for analysis of 160 observations (table 1).

Table 1. Type and timing of for the deployment of carcasses during the carcass persistence trials.

SPECIES TYPE	SEP (2018)	JAN (2019)	APR (2019)	JUL (2019)	JUL (2020)	OCT (2020)	JAN (2021)	APR (2021)
BAT	4	4	4	4	6	8	8	10
BIRD OF PREY	4	2	0	4	0	1	3	2
EAGLE	5	4	4	3	3	0	3	2
MEDIUM BIRD	2	4	4	6	7	10	7	6
MOUSE	4	3	4	4	0	0	0	0
SMALL BIRD	4	4	3	0	0	0	0	0

[*] Noting that the fourth trial in year 1 extended into year 2.

Monitoring of carcasses occurred for 31 days except for the wedge-tailed eagles (WTE) which were monitored until no evidence of the carcass was available. All carcasses were placed within the survey area of the turbines during the September 2018 trial, however, following the discovery of WTE's as the primary scavengers of other WTE's, WTE carcasses were placed greater than 200m from the turbine base to reduce the risk of collisions for subsequent trials. No mice were placed in the year 3 persistence trials as bats were readily available, additionally no small birds were placed as they were unavailable at the time of the study.

2.2.1 Data Analysis

Survival analysis was used to determine the average time carcasses remained in the field before scavenging. As an exact time of removal is not known for all carcasses, survival analysis provides an interval in which the scavenge event has occurred and fits a curve to the data which is used to estimate the average survival percentage after a given length of time. Survival analysis is used to fit a curve to the data which provides an estimate of the survival percentage after a given length of time (full details in Symbolix reports, see Appendix 2).

2.3 Searcher Efficiency

Searcher efficiency trials were conducted in years 1 and 3 of the study to determine the likelihood of the survey team detecting a carcass during surveys if one is present. Trials for Year 2 were repeatedly delayed and ultimately not completed due to the complications imposed by Covid. Data for the same dog and handler teams were compiled from seven trials at three other Victorian sites to increase the confidence around searcher efficiency and to increase the sample size to 175 targets. This comparison across seasons and sites is a methodology adopted at other windfarms and approved by DELWP to increase the sample size and confidence around searcher efficiency. Methodology used is consistent at Yaloak South and other wind farms sites as outlined below.

Carcasses are randomly distributed throughout the survey area at least 1 hour prior to the arrival of the search team. To ensure dogs are not tracking human footsteps, carcasses are thrown from a randomly designated point and allowed to land naturally. GPS coordinates of the throw location and direction of throw are recorded, and an indirect path is walked back to the vehicle. Whilst handlers are aware of the trial being undertaken, the trial is still considered blind as handlers are unaware of the number and type of carcasses present, which turbines are baited, nor which turbines remain unbaited thus providing sufficient blinding to validate the testing. To ensure additional effort is not made by dogs and handlers, GPS tracking of the dogs and handlers records survey duration which can be compared to standard surveys to ensure the dog team does not spend longer looking during an efficiency trial.

2.3.1 Data Analysis

Observer efficiency data was provided to Symbolix to allow for correction based on observational bias. The dog and handler teams engaged at Yaloak South Wind Farm are simultaneously engaged in work at other wind energy facilities within Victoria and all searcher efficiency data was provided to Symbolix. Trials conducted at Yaloak South in year one and three of the program were compared with additional trials conducted on the same team at different wind farms during the same time period and analysed for differences using binomial regression and stepwise AIC selection.

2.4 Carcass Searches

Carcasses surveys have been conducted by trained detection dogs and their handlers weekly between July 2018 and June 2019, fortnightly between June 2019 and December 2019 and monthly from January 2019 to June 2021 at all 14 turbines to a radius of 60m. Additional "pulse" surveys were conducted between November and May in each of the three years of the BAMP program for the detection of bats. Pulse surveys occur 3 days after the scheduled survey and assist by shortening the survey interval and thus the influence of scavenging activity on final mortality estimates for small carcasses. A total of 1355 surveys were undertaken at the 14 turbines over the three year period. Occasionally, turbines were unable to be searched due to health and safety reasons and were not accessible to the dog and handler. Full details of the number of surveys can be found in Table 2.

Table 2 Number of surveys per month, note that some months had 5 weeks and others 4.

Month	Number of surveys	Reduced survey reason
July 2018	70	Weekly surveys commenced
August 2018	46	Lambing[†] turbines 10 to 14
September 2018	46	Lambing[†] turbines 10 to 14
October 2018	83	1 turbine not surveyed due to operational maintenance
November 2018	69	1 turbine not surveyed due to operational maintenance
December 2018	84	
January 2019	69	1 turbine not surveyed due to operational maintenance
February 2019	69	1 turbine not surveyed due to operational maintenance
March 2019	70	
April 2019	68	2 turbines not surveyed due to operational maintenance
May 2019	42	Shift to fortnightly surveys
June 2019	28	
July 2019	42	
August 2019	28	
September 2019	28	
October 2019	42	
November 2019	42	
December 2019	28	Monthly surveys (with summer pulse) commenced
January 2020	28	
February 2020	28	
March 2020	28	
April 2020	28	
May 2020	14	
June 2020	14	
July 2020	13	1 turbine not surveyed due to operational maintenance
August 2020	13	1 turbine not surveyed due to operational maintenance
September 2020	14	
October 2020	28	
November 2020	28	
December 2020	28	
January 2021	27	1 turbine not surveyed due to operational maintenance
February 2021	28	
March 2021	27	1 turbine not surveyed due to operational maintenance
April 2021	28	
May 2021	13	1 turbine not surveyed due to operational maintenance
June 2021	14	

[†] In the first year of operation, farming managers were still lambing within the turbine area which reduced access for the dogs to undertake surveys, post September 2018 no more lambing occurred in the paddocks occupied by turbines as per the requirements of the BAMP.

2.4.1 Data Analysis

The mortality estimation is done via three Monte-Carlo simulations, one for bats, one for birds (excluding eagles) and one for WTE's. Each used 25,000 simulations of the survey design. Random numbers of virtual mortalities were constructed, along with the scavenge loss time and searcher efficiency (based on the measured confidence intervals) and correction factors for area surveyed were applied based on estimates from Hull and Muir (2010) which assumes a 60m survey covers the fall zone of 95% of bats and 61% of birds. 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) were reported on.

This simulator has been found to perform comparably to other theoretical estimators, but more easily incorporates changing or complex survey designs. An explanation of the analysis can be found in Appendix 5.

3 RESULTS

3.1 Searcher Efficiency

Searcher efficiency was assessed in years 1 and 3 (Appendix 4). Searcher efficiency trials were carried out at Yaloak South Wind Farm and three other wind farms during the same time period on the same dog/ handler teams. There was no evidence that searcher efficiency differed between the sites, the dog/handler team or the target (different sized birds or bat), thus data was aggregated into a single estimate to provide a stronger confidence of the mean. Searcher efficiency was 91% with a 95% confidence interval of [86%, 95%] (Table 3).

Table 3 Detection efficiency for dog and handler team combined

Variable	Combined estimate
Number found	159
Number placed	175
Mean detectability proportion	0.91
Detectability lower bound (95% confidence interval)	0.86
Detectability upper bound (95% confidence interval)	0.95

3.2 Carcass persistence trials – years 1 and 3 combined

Four carcass persistence trials were conducted in each season of the first year[‡] and four conducted in each season of year 3 with a total of 160 carcasses with complete data used for analysis. There were 24 carcasses remaining after 30 days (considered the end of each trial), 19 of which were eagles. During analysis it was found that bats and mice were not significantly different in their removal rates and thus they were combined as a single category. Similarly, it was found that small birds, medium birds and birds of prey (excluding eagles) were best described as a single category for scavenger removal. Thus, three different scavenging rates were determined: one for bats, one for eagles and one for all other birds.

Survival curves fitted to the scavenge data shows a difference between the scavenge rate of bats, birds and WTE's with the assumption that all scavengers are "perfect", that is, the carcass is completely removed from the survey area (Figure 2). The average time for loss of bats is 2.2 days with a 95% confidence interval of [1.5, 3.2] days. The average time for birds (not including WTE's) is 2.8 days with a 95% confidence interval of [2, 4] days. For WTE's, the mean time to total loss by scavengers is 260 days, with a 95% confidence interval of [119, 567] days. Total loss refers to a loss of all evidence including feather spots.

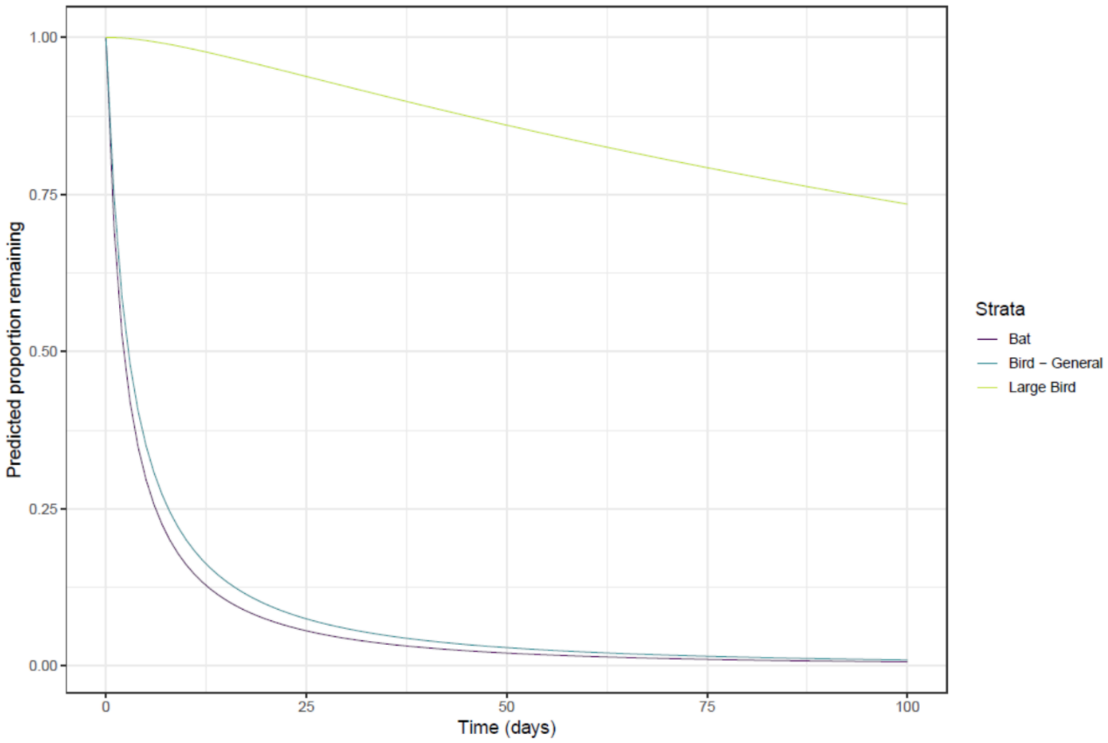

Figure 2 Survival curve showing difference persistence for WTE (large bird), birds and bats.

‡ Noting that the fourth trial extended into the second year (See Section 2.2).

3.3 Carcass Searches

Carcass searches for year 3 were carried out between July 2020 and June 2021 at every turbine, with the exception of 5 surveys that were missed due to health and safety with access restrictions for turbine repairs at the time of survey. In total 261 turbine searches were carried at the 14 turbines (Table 2).

A total of 33 bats and 12 birds or feather spots (including WTE's) were found during routine mortality searches (Table 4) with an additional 1 bird found outside routine surveys (Table 5). Four WTE's, considered a species of interest at this site, and one white throated needle tail, listed in the EPBC Act, were found during the period of this report (year 3).

Table 4 Summary of species found during carcass searches in year 3

	Species	Count
bats	Eastern falsistrelle	2
	Gould's wattled bat	9
	White striped freetail bat	9
	Lesser long eared bat	2
	Little forest bat	5
	Southern forest bat	3
	Chocolate wattled bat	2
	Large forest bat	1
Birds	Wedge-tailed eagle	4
	Magpie	1
	Bronze Wing Pigeon	1
	Brown Falcon	1
	Chestnut teal	1
	White-throated needletail	1
	Nankeen kestrel	2
	Sparrow	1

Table 5 Incidental finds found outside routine survey area

Species	Date
Nankeen kestrel	1/3/2021

3.3.1 Year 3 - Mortality estimation for bats

During the third year survey period, a total of 33 bats were found at Yaloak South with half of finds detected during standard surveys, and half during pulse surveys. Bat finds only occurred between November and June, with half of all bats found during the 2 month period of March and April. The resulting estimate, taking into consideration scavenger removal and searcher efficiency, is a mean loss of 186 bats for the year. Based on the detected carcasses there is 95% confidence that fewer than 259 individual bats were lost across the site (Figure 3).

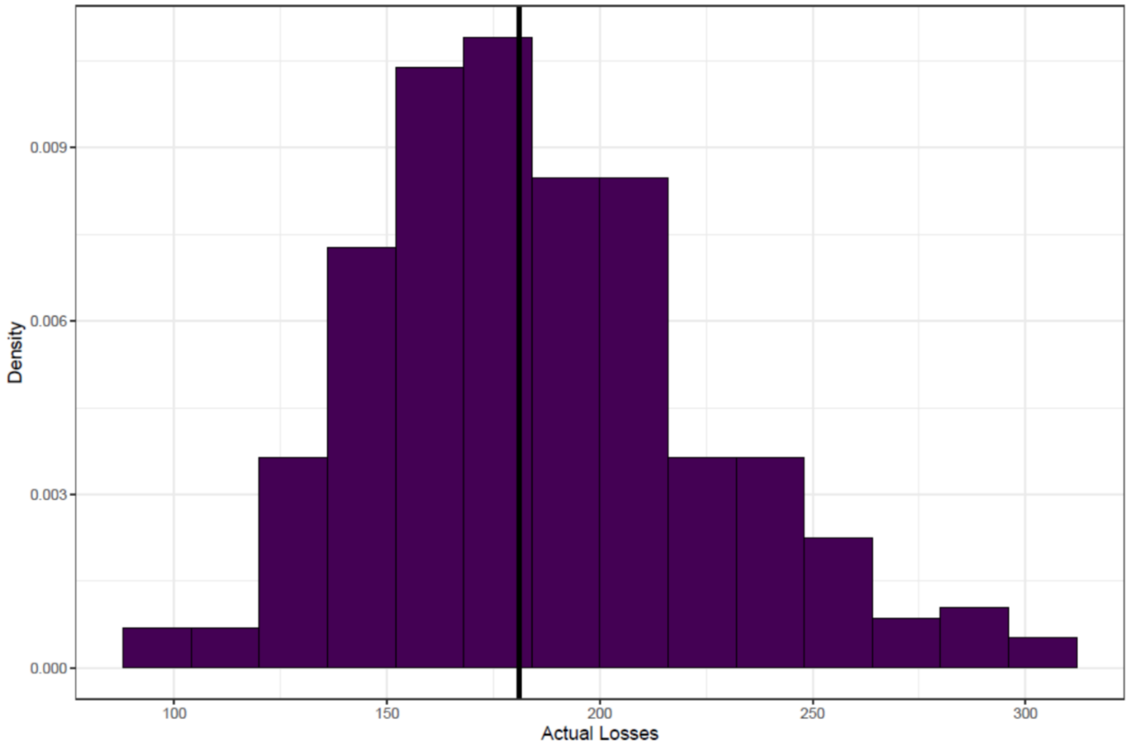

Figure 3 Histogram of bat losses at Yaloak South Wind Farm. The solid black line indicates the median

3.3.2 Year 3 - Mortality estimation for birds

During the routine mortality surveys in the third year, a total of 8 birds (excluding WTE's) were found at Yaloak South Wind Farm. The resulting estimate taking into consideration scavenger removal and searcher efficiency is a mean loss of 55 birds for the period (excluding wedge-tailed eagles). This estimation also includes correction factors for a 60m search area and is thus accounting for birds "missed" outside the survey area (Hull and Muir 2010). Based on the detected carcasses there is 95% confidence that fewer than 89 birds (Figure 4) were lost.

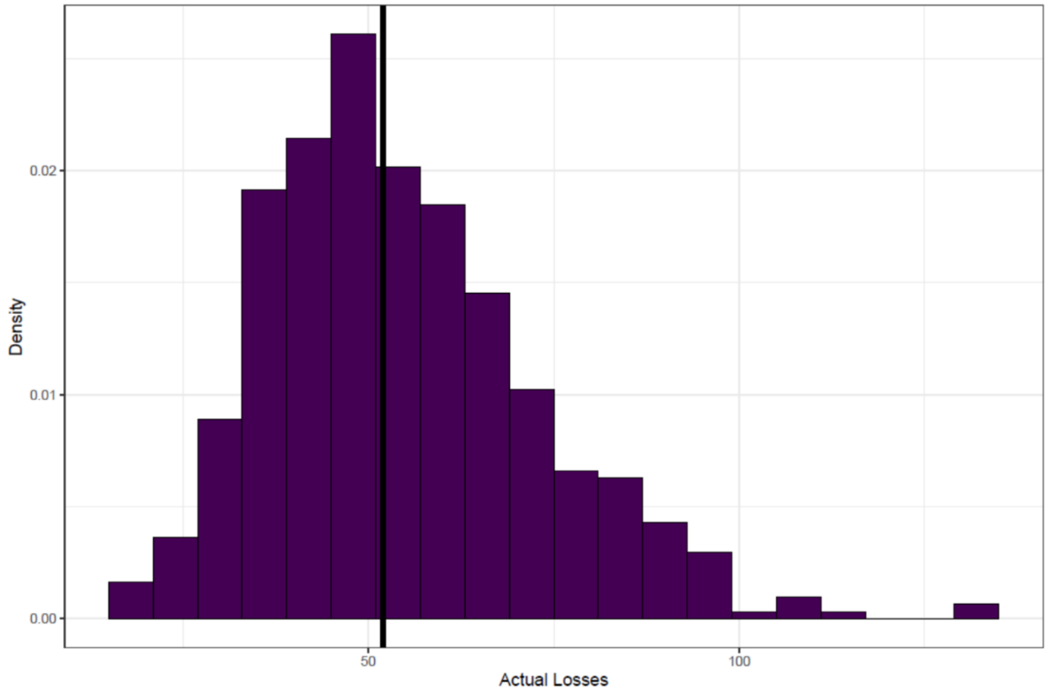

Figure 4 Histogram of bird losses (excluding wedge-tailed eagles) at Yaloak South Wind Farm. The solid black line indicates the median.

3.3.3 Year 3 – Mortality estimation for wedge-tailed eagles

During the third year of routine mortality surveys a total of 4 wedge-tailed eagles were found at Yaloak South Wind Farm. Taking into consideration carcass persistence and searcher efficiency, for WTE's there is an expected mean loss of 5 birds over the 12 month study period. Based on these estimates we can be 95% confident that fewer than 7 eagles were lost (Figure 5). Given the persistence of eagles and the ease of eagle carcass detection, it is likely that these 4 eagles represent all eagles killed at Yaloak South Wind Farm during the survey period.

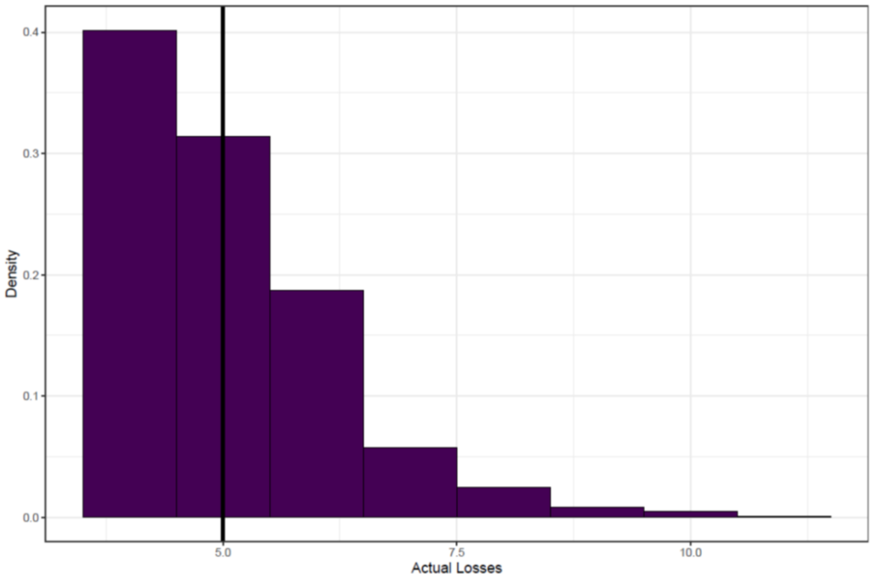

Figure 5 Histogram of wedge-tailed eagle losses at Yaloak South Wind Farm. The solid black line indicates the median.

3.3.4 Results - Years 1 to 3

The estimated impact to bats over the three years of the study is relatively consistent with more confidence in the estimate in year 1 of the study where search effort was highest (Table 6). The estimates for birds and WTE's is not significantly different between the years, although higher estimates are derived for years 2 and 3 where search effort and confidence levels was reduced, but overlapping confidence intervals (Figure 6) demonstrate that the true value may be more consistent. In addition, the low number of finds for birds makes drawing conclusions around estimates less certain.

Table 6 Summary of actual and estimated mortality over the three years of mortality monitoring

	Year 1	Year 2	Year 3
Bats (found)	73	35	33
Bats (estimated)	187 [121, 231]	171 [94, 233]	186 [102, 259]
Birds (excluding eagles) (found)	7	11	8
Birds (excluding eagles) (estimated)	17 [8, 26]	42 [19, 62]	55 [16, 89]
Wedge-tailed Eagles (found)	4	3	4
Wedge-tailed Eagles (estimated)	-[§]	3 [2, 4]	5 [4, 7]

[§] Due to the search effort in year 1, it was considered that all WTEs impacted were found and thus no estimation was derived.

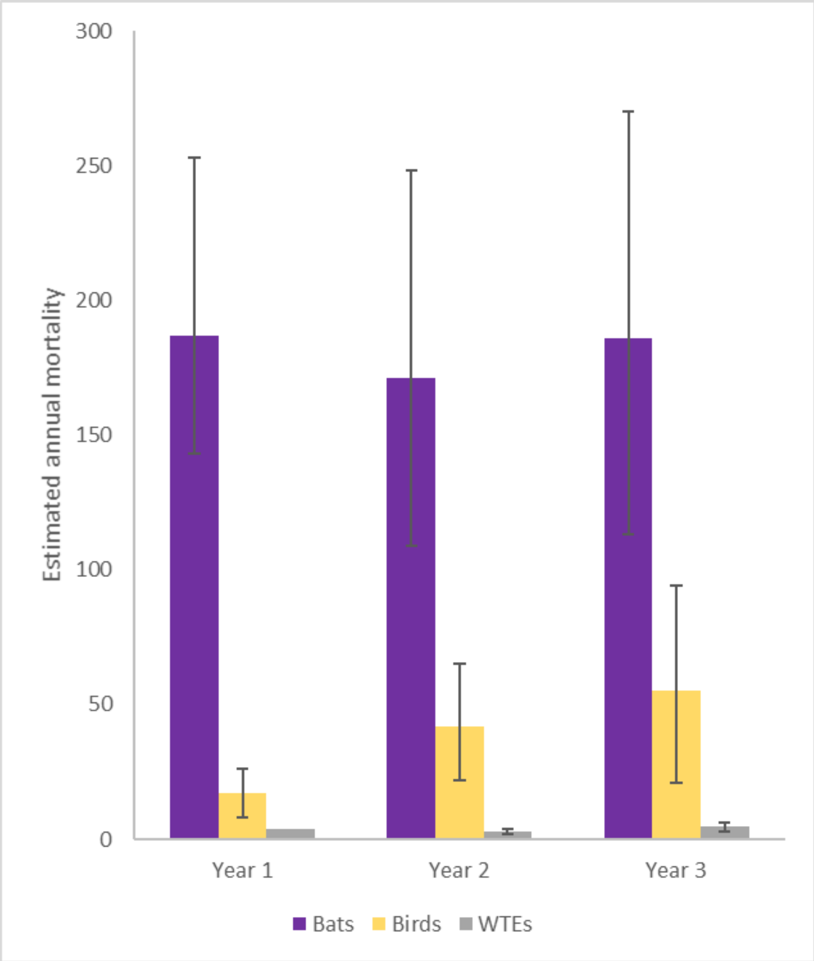

Figure 6 Estimated mortality of bats, birds and WTE's at Yaloak South Wind Farm 2018 to 2020

4 DISCUSSION

4.1 Searcher Efficiency

Results for the detection of both birds and bats is 91% [86%, 95%] and is consistent with other sites utilising the same dog/ handler teams. There was no difference in the detectability of birds and bats by the dog/ handler teams and this is primarily driven by the dogs' use of olfactory detection rather than visual based searches. The use of dogs is particularly advantageous for small targets such as bats and small birds where evidence suggests that humans have low detection rates (Mathews et al. 2013).

4.2 Carcass Persistence

It was demonstrated in the 8 trials conducted at Yaloak South that the persistence of carcasses in the landscape does vary by size and type of carcass, with the best fit model also determining that season contributed as an influence to scavenging rates. Bats and mice were scavenged at a faster rate than smaller or similar sized birds, whilst there was no measurable difference in the scavenging rates of medium birds, birds of prey such as kestrels, or small birds such as quail or sparrows. Significantly, it was demonstrated that the persistence of wedge-tailed eagles is much greater than that of other birds or bats, with 19 of 24 carcasses persisting for longer than 30 days and that on average there was still an 90% probability of a carcass persisting past 30 days (Appendix 2). Carcass persistence was incorporated into the model based on the size and type of carcass providing a more realistic approach to persistence than a single removal rate for all birds, bats and eagles.

4.3 Carcass Searches

Overall mortality estimates for bats at Yaloak South Wind Farm provide 95% confidence that no more than 259 bats were impacted during the third year of monitoring. The average number of bats likely to have been impacted per turbine in year three is 13.2, with 95% confidence that less than 18.5 bats were impacted. Considering the temporal patterns of bats, around half of all bats impacted are likely to occur during March and April, with little to no impacts occurring from winter to mid spring.

The diversity of bat species found at Yaloak South Wind Farm is indicative of the location of the site. The proximity of forests within Brisbane Ranges National Park and the open farm land of the wind farm itself provides an intersection of forest and open landscapes. Species such as white striped freetail bats (*Tadarida australis*) are typical of farm lands and open areas, whilst the forest bats (*Vespadelus species*) are more frequently associated with forested sites. In comparison with other sites in western Victoria, bat impacts are slightly above the state average, although it needs to be considered that survey methods at Yaloak are more likely to detect bats than other facilities which are not engaging dogs or undertaking pulse surveys.

Overall mortality estimates for birds (excluding WTE's) at Yaloak South Wind Farm provide 95% confidence that no more than 89 birds were impacted during the third year of monitoring. The average number of birds likely to be impacted per turbine for year three is 3.9 birds, with a 95% confidence that less than 6.4 birds per turbine were impacted. This estimate is consistent with other sites in Victoria (Symbolix, 2020). It also should be noted that the number of bird carcasses found has remained consistent between years and the estimate has increased due to the reduced search effort and the greater uncertainty this can introduce. It is possible that the model over estimates the number of collisions given the consistent number of finds, higher detection rates for dog searches and that all turbines at the site were searched increasing opportunities for detection relative to other wind farms.

The estimated number of eagles impacted was 5, with 95% confidence that fewer than 7 eagles were impacted across the entire site during the year. These figures take into consideration the 60m search area, searcher efficiency and carcass persistence and are a robust estimation of the true impact.

4.4 Comparison of Years

The total number of bat losses was significantly higher in year 3 than in years 1 and 2 using the Kolmogorov-Smirnov statistical test (Appendix 1). In comparison, the small number of birds detected each year (Table 6) means that difference between the each year's estimates are influenced by just a few additional finds, however no significant difference was found between years 2 and 3. Such low number of finds mean that statements of differences cannot be made with great confidence and that true values may not differ.

The total number of eagles found during all three years of this study is 11. Given the information obtained through the scavenger trials this is likely to represent all eagles impacted at the site and is well below the threshold for further action as outlined in the BAM plan. Therefore the number of eagles impacted at this site will not impact the population viability of wedge-tailed eagles.

4.5 Significant Impacts

Events considered or defined as a significant impact are outlined in section 3, Volume 1 of the endorsed Bat and Avifauna Management Plan for Yaloak South Wind Farm. One White throated needle tail (*Hirundapus caudacutus*) was detected in February 2021 (year 3). This species is listed as migratory and vulnerable under the federal EPBC Act (as of 4th July 2019) and threatened under the Victorian FFG Act as of January 2021. The occurrence was reported to DEWLP once the bird was identified. No other species found were listed under any of the relevant legislations, Commonwealth EPBC Act, Victoria's FFG Act or the Advisory list of threatened vertebrate fauna in Victoria (DSE 2013).

Wedge-tailed eagles are not considered to be under any level of threat on the Australian mainland, however the level of impact to individuals at Yaloak South Wind Farm was a primary consideration of the post construction mortality monitoring program. Modelled projections of up to 6.7 WTE's annually was considered to pose no threat to the species' population[**]. The 4 eagles impacted in the third year of operation is less than this modelled projection and is therefore considered to have a negligible impact to the population of eagles. Overall the impact to eagles is below the modelled 6.7 birds per year and therefore Yaloak South Wind Farm does not pose a threat to the species population.

[**] Yaloak South Wind Energy Facility – Advisory Committee Report, September 2010 (Permit Application Ref 2010/002, Application for Review Ref P664/2010)

5. RECOMMENDATIONS

5.1 Further Investigations

Impacts have been generally consistent through the first three years of operation at Yaloak South Wind Farm, whilst acknowledging the increased estimate to bat impacts in year 3. These impacts are below or within expectations of planning approvals for such a facility. There is no evidence to suggest that impacts are likely to change in subsequent years and therefore further monitoring is not warranted. The information presented in the first three years of operation is sufficient for DEWLP to ascertain the ongoing impact of Yaloak South Wind Farm on bird and bats within the local area. There are no recommendations for further monitoring or action at Yaloak South Wind Farm.

6. REFERENCES

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7. APPENDIX

1. Symbolix Report Yaloak Wind Farm Mortality Estimate Year 3
2. Symbolix Report Eagle Scavenger Trial Analysis
3. List of finds years 1 to 3
4. Searcher Efficiency Trial Yaloak South Year 3
5. Monte-Carlo simulations explained

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Appendix 1

Yaloak South Wind Farm Mortality Estimate - Year 3

Prepared for Elmoby Ecology, 29 July 2021, Ver. 1.0

This report outlines an analysis of the mortality data collected at the Yaloak South Wind Farm from 2018-07-02 to 2021-06-01. The analysis is broken into the three related components below:

- Searcher efficiency / detectability – Trials were conducted at Yaloak South Wind Farm in April 2019 and October 2020
  - Elmoby Ecology also provided data from detectability trials conducted at three other Victorian wind farms (using identical field techniques). We pooled the data (after confirming there was no statistically significant difference) to generate a more precise estimate of detectability.
- Scavenger loss rates – consisting of trials in: September 2018, January 2019, April 2019, July 2019, July 2020, October 2020, January 2021 and April 2021
- Mortality estimates - based on monthly surveys at all 14 turbines, from 2018-07-02 to 2021-06-01

The data was collected and provided by Elmoby Ecology. 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

Data was collected, verified and provided to us from Elmoby Ecology[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. We used a Monte-Carlo simulation to achieve this.

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

[1] Elmoby_Mortality_Template.xlsx, Yaloak scav trial complete.xlsx, detection combined.xlsx

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 (Huso (2011), 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

Seven searcher efficiency trials were held. The data provided for this analysis included two Yaloak South trials; in addition, data from seven trials at three other Victorian sites was used (collected using identical field techniques).

A range of bird and bat sizes were used. Canine searchers were used for all trials.

The detectability at Yaloak South was not significantly different to the other sites, so the mean and confidence intervals used in the model were based on pooled data. This provides a more precise estimate (i.e. smaller confidence interval).

We also found no evidence (using binomial generalised linear modelling) that the searcher efficiency differed between species types (via stepwise AIC selection). We therefore aggregated all trials into a single estimate of searcher efficiency rate.

Table 1 summarises the result.

Detectability is 91%, with a 95% confidence interval of [86%, 95%].

Table 1: Detection efficiency combined.

Variable	Combined estimate
Number found	159
Number placed	175
Mean detectability proportion	0.91
Detectability lower bound (95% confidence interval)	0.86
Detectability upper bound (95% confidence interval)	0.95

Scavenger efficiency

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.

We fit survival regression curves in using the techniques of Terry M. Therneau and Patricia M. Grambsch (2000), under the assumption of log-normally distributed data. We note this is different from last year's report (Symbolix 2020), where we assumed an exponential scavenge shape. In the last year, evidence supporting the use of log-normal distributions to model time-to-scavenge has emerged, and this has now become our standard (Stark and Muir 2020).

Based on these surveys there is evidence (via AIC) of a difference in scavenger rates between bats, Wedge-tailed Eagles, and other birds.

Figure 1 shows a survival curve fitted to cohorts of bats, Wedge-tailed Eagles, and other birds. All data was collected at the Yaloak South Wind Farm. The survival curves show the estimated proportion of the sets remaining at any given time. For example, we see that we expect around 14% of bat carcasses to remain after ten days.

Under these assumptions, for bats, the median time to total loss via scavenge is 2.2 days, with a 95% confidence window of [1.5, 3.2] days. For birds (not including Wedge-tailed Eagles), the median time to total loss via scavenge is 2.8 days, with a 95% confidence window of [2, 4] days. For Wedge-tailed Eagles, the median time to total loss via scavenge is 260 days, with a 95% confidence window of [119.1, 567.5] days.

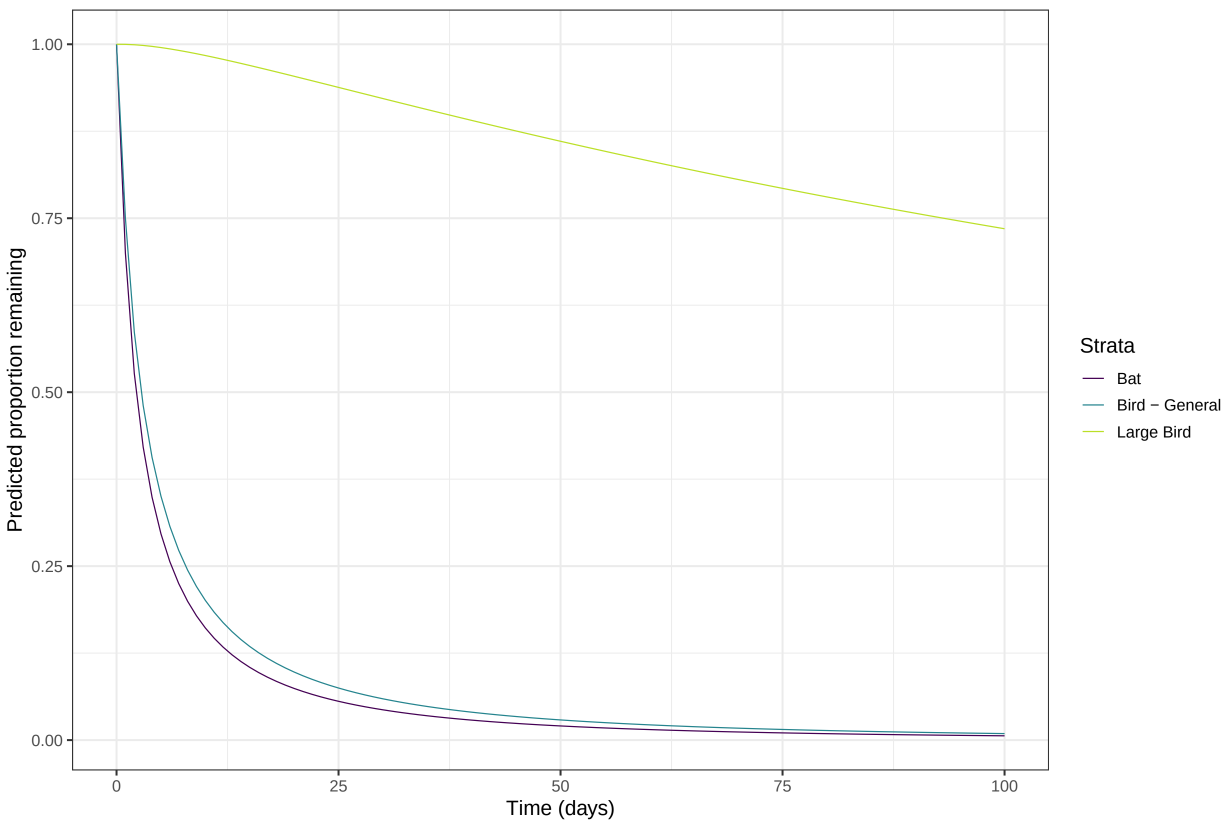

Figure 1: Combined survival curves for birds (excluding Wedge-tailed Eagles), Wedge-tailed Eagles, bats.

Because the scavenger rates for Wedge-tailed Eagles and other birds are different, we provide separate mortality estimates for Wedge-tailed Eagles and other birds.

Mortality projection inputs

Carcass search data

The third year mortality estimate was based on a dated list of turbine surveys. The survey frequency is summarised in Table 2. All turbines were surveyed out to a radius of 60 metres (where possible; sometimes weather / safety etc. issues prevented the full area from being searched).

Table 2: Number of surveys per month in the third year of surveys.

Date	Number of surveys
2020 Jul	13
2020 Aug	13
2020 Sep	14
2020 Oct	28
2020 Nov	28
2020 Dec	28
2021 Jan	27
2021 Feb	28
2021 Mar	27
2021 Apr	28
2021 May	13
2021 Jun	14

Mortality estimate

Mortality estimation – methodology

With estimates for scavenge loss and searcher efficiency we then converted the number of bat and bird carcasses detected into annual estimates of mortality at Yaloak South Wind Farm over the the third year of surveying, from 2020-06-03 to 2021-06-01 (we allow for collisions to occur up to a month prior to the first survey). We report the third year's mortality estimate, and compare it to the second year's estimate.

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 14 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 up to a month before the initial survey (2020-07-07) and until the final surveyed date (2021-06-01).
- Birds are on-site at all times during this period.
- Bats are on-site at all times during this period.
- 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 an lognormal scavenge shape.
- We took scavenge loss and search efficiency rates as outlined above.
- All turbines were surveyed, and were searched out to a (usually) 60 metre radius. We estimated the "coverage factor" for the survey program as a whole – i.e. the average proportion of total fall zone for birds / bats / WTEs (using estimates from Hull and Muir (2010)) covered by each survey. We assumed that the coverage factor was 61% for birds (excluding Wedge-tailed Eagles), 47% for Wedge-tailed Eagles, and 94% 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 in the third year of surveys.

Year	Species	Bat	Bird	Feather Spot
3	gould's wattled bat	9	0	0
3	white-striped freetail	9	0	0
3	little forest bat	5	0	0
3	southern forest bat	3	0	0
3	chocolate wattled bat	2	0	0
3	eastern falsistrelle	2	0	0
3	lesser long eared bat	2	0	0
3	large forest bat	1	0	0
3	wedge-tailed eagle	0	4	0
3	nankeen kestrel	0	1	1
3	brown falcon	0	1	0
3	chestnut teal	0	1	0
3	common bronzewing pigeon	0	1	0
3	sparrow	0	1	0
3	white-throated needletail	0	1	0
3	magpie	0	0	1

There were also a small number of "incidental" finds (see Table 4), which were carcasses found outside the formal survey area. These finds are not included in the formal mortality estimate.

Table 4: Incidental finds (carcasses found outside the 60 m search area).

Species	Date	Year
nankeen kestrel	2021-03-01	3

Year three results

Bird results

During the third year of surveys a total of eight birds (excluding Wedge-tailed Eagles) and four Wedge-tailed Eagles 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 55 and a median of 52 birds (excluding Wedge-tailed Eagles) lost on site over the twelve months. For Wedge-tailed Eagles, the estimate is an expectation (mean) of of 5 and a median of 5 birds.

Tables 5 and 6, and Figures 2 and 3, display the percentiles of the distributions to show the confidence interval in these averages.

In determining the estimate, we have used the standard practice of assuming that all carcasses and all feather spots (regardless of size or composition) are attributable to the wind turbines.

Based on the detected carcasses and feather spots and measured detectability and scavenge rate, we expect that there was a total site loss of around 55 birds (excluding Wedge-tailed Eagles) and around 5 Wedge-tailed Eagles over the survey period, and are 95% confident that fewer than 89 birds (excluding Wedge-tailed Eagles) and 7 Wedge-tailed Eagles were lost.

Table 5: Percentiles of estimated total bird losses (excluding Wedge-tailed Eagles) over year three of surveying.

0%	50% (median)	90%	95%	99%	99.9%
16	52	80	89	109	133

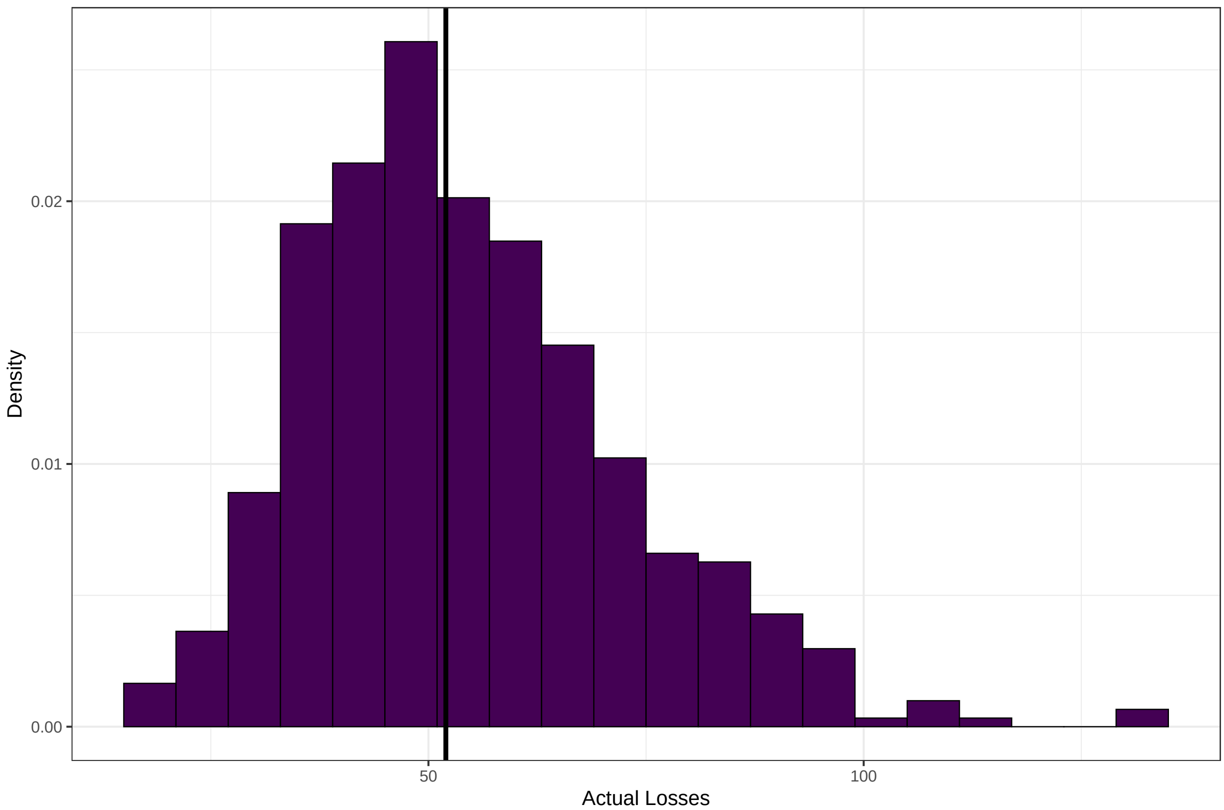

Figure 2: Histogram of the total losses distribution (birds - Wedge-tailed Eagles excluded), given eight were detected on-site. The black solid line shows the median.

Table 6: Percentiles of estimated total Wedge-tailed Eagle losses over year three of the surveying.

0%	50% (median)	90%	95%	99%	99.9%
4	5	6	7	9	10

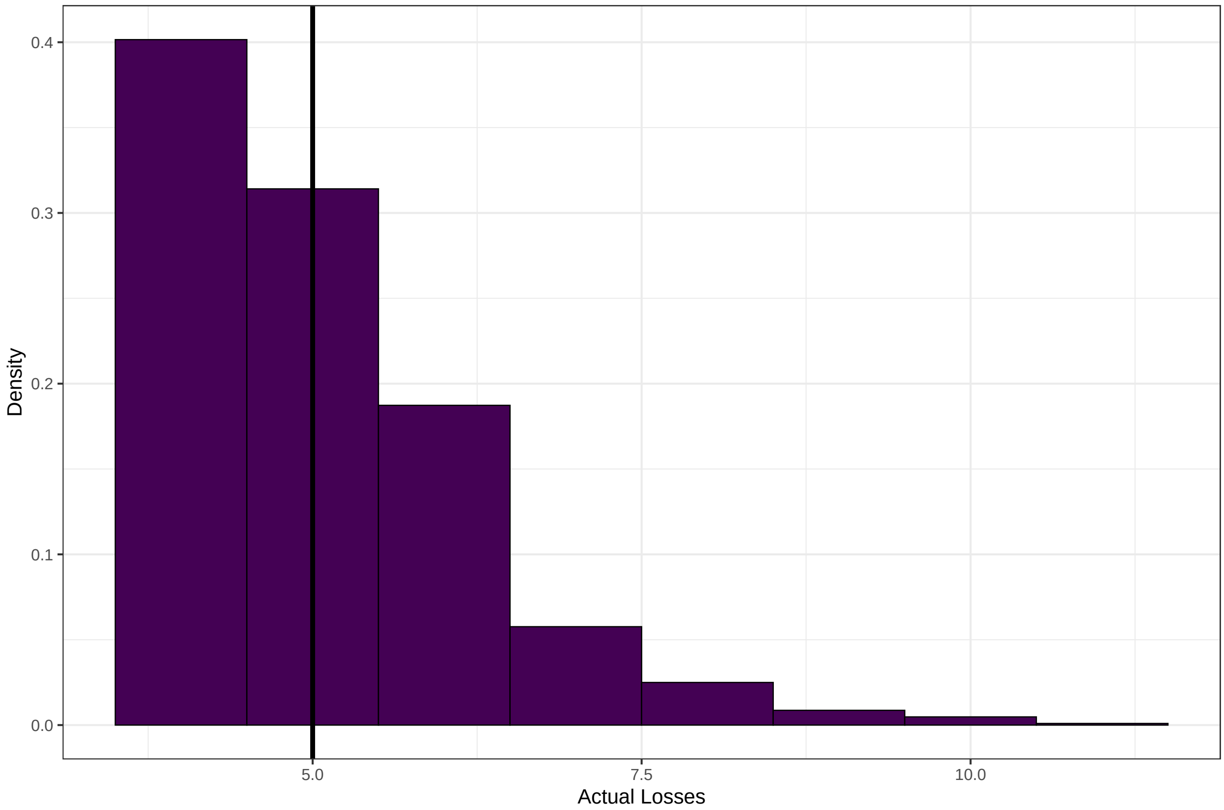

Figure 3: Histogram of the total losses distribution for Wedge-tailed Eagles, given two were detected on-site. The black solid line shows the median.

Bat results

During third year of surveys a total of 33 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 186 and a median of 181 bats lost on site over the twelve months.

Table 7 and Figure 4 and display the percentiles of the distributions to show the confidence interval in these averages.

Based on the detected carcasses and measured detectability and scavenge rate, we expect that there was a total site loss of around 186 bats, and are 95% confident that fewer than 259 bats were lost.

Table 7: Percentiles of estimated total bat losses over year three of the survey period.

0%	50% (median)	90%	95%	99%	99.9%
102	181	237	259	285	300

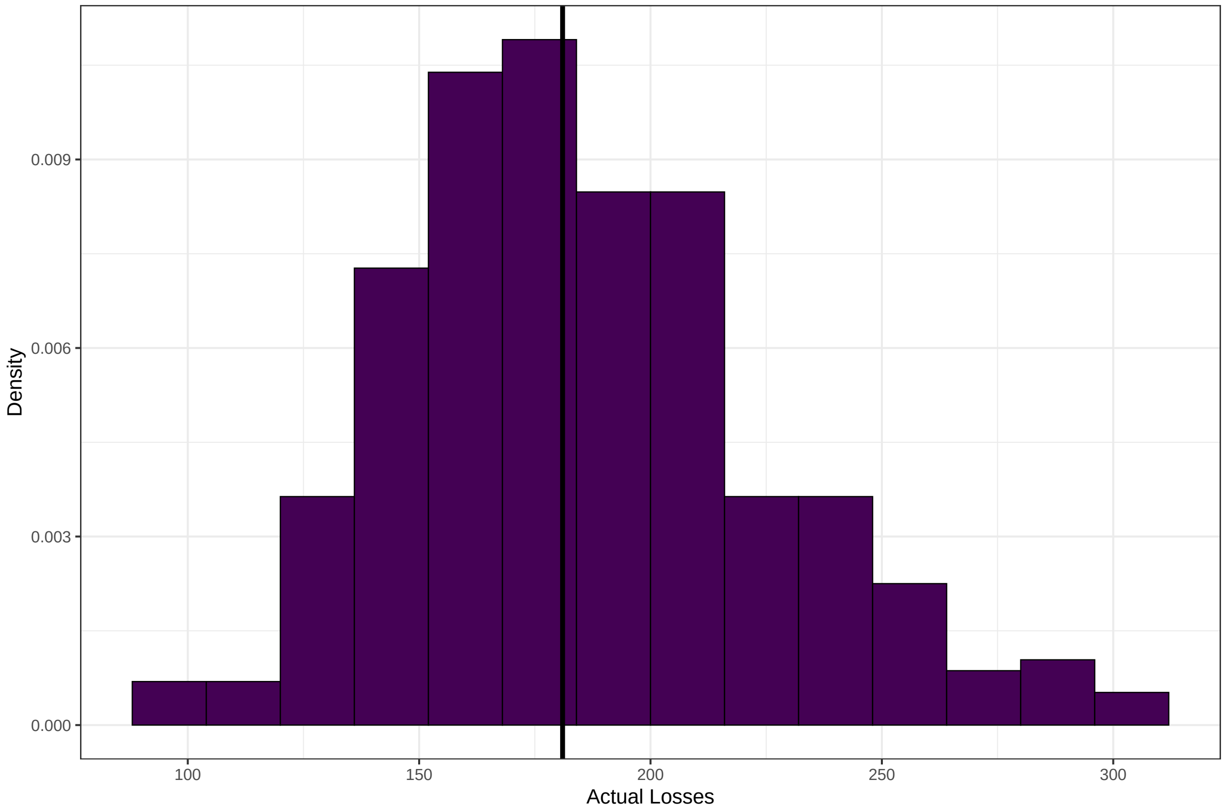

Figure 4: Histogram of the total losses distribution (bats), given 33 were detected on-site. The black solid line shows the median.

Comparison of years two and three

Bat results

During the second year of surveys (2019-06-02 to 2020-06-02) a total of 35 bats were found during formal surveys[2]. The resulting estimate of total mortality is an expectation (mean) of around 156 bats over the survey period, and we are 95% confident that fewer than 219 individuals were lost.

In comparison, in the third year of surveys a total of 33 bats were found during formal surveys. The resulting estimate of total mortality is an expectation of 186 bats over the survey period, and we are 95% confident that fewer than 259 individuals were lost.

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 two and year three. There was a significant difference between the second and third years ($K = 0.365$ is greater than the critical value, $K_{0.05} = 0.351$). Assuming all model assumptions hold, this would imply that the true total number of bat losses in year three was significantly higher than the

[2]Note: there are differences in the reported Year 2 bat and bird mortality estimates in this report, compared with in Symbolix (2020) due to the updated scavenger and detection models.

number of losses in year two.

Bird results

During the second year of surveys a total of 11 birds (excluding Wedge-tailed Eagles) were found during formal surveys, and two Wedge-tailed Eagles. The resulting estimate of total mortality is an expectation of around 57 birds (excluding Wedge-tailed Eagles) over the survey period, and we are 95% confident that fewer than 89 individuals were lost. We expect three WTEs were lost, and are 95% confident that fewer than four individuals were lost.

In comparison, in the third year of surveys a total of eight birds (excluding Wedge-tailed Eagles) were found during formal surveys. Four Wedge-tailed eagles were found. The resulting estimate of total mortality for birds (excluding Wedge-tailed Eagles) is an expectation of 55 birds over the survey period, and we are 95% confident that fewer than 89 individuals were lost. We expect five WTEs were lost, and are 95% that fewer than seven individuals were lost.

When considering all non-WTE bird mortalities, we did not find the distribution of the second year to be different from the distribution of year three mortalities ($K = 0.065$ is less than the critical value, $K_{0.05} = 0.351$).

However, the distributions of WTE mortalities in the second and third years are significantly different ($K = 0.893$ is greater than the critical value, $K_{0.05} = 0.351$). We find the distribution of WTE mortalities of the second year to be shifted left. Assuming all model assumptions hold, this would imply that the true total number of WTE losses in year three was significantly higher than the number of losses in year two. However, we note that the results should be taken with caution due to the low count of Wedge-tailed eagles found.

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 or birds that could be onsite, and we assumed that bats and birds were present all year round. The ecological feasibility of this assumption should be accounted for if using these results to comment on overall ecological impact.

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Appendix 2

Eagle Scavenger Trial Analysis

Prepared for Elmoby Ecology, 12 September 2019, Ver. 1.0

1 Background

The purpose of this study is to quantify the removal rates of a range of carcass sizes at Yaloak Wind Farm in Western Victoria. We are testing the hypothesis that there is no difference in the removal rate of eagles, passerines, small birds and bats by scavengers.

1.1 Data

Scavenger trials at Yaloak Wind Farm were held starting on the following dates: 2018 Sep, 2019 Jan, 2019 Apr, 2019 Jul. The aim was to place 24 carcasses per trial - 4 eagles, 4 birds of prey, 4 medium passerines, 4 small passerines, 4 bats, and 4 mice.

The final data set was comprised of the species summarised in Table 1. In total, we had a final set of 84 observations. We note that an additional five were placed, but data was not available due to corrupted files.

Table 1: Summary of carcass types placed over the trial.

Species Type	2018 Sep	2019 Jan	2019 Apr	2019 Jul
bat	4	4	4	4
bird of prey	4	2	0	4
eagle	5	4	4	3
medium bird	2	4	4	6
mouse	4	3	4	4
small bird	4	4	3	0

Eagles placed are summarised in Table 2.

Table 2: Number of eagles placed.

Species	Date	Carcasses
wedge-tailed eagle	2018 Sep	5
wedge-tailed eagle	2019 Jan	3
little eagle	2019 Jan	1
wedge-tailed eagle	2019 Apr	4
wedge-tailed eagle	2019 Jul	3

Of all the carcasses placed, 14 were still remaining at the end of the trial. Of these, 12 were eagles.

For more information on how the data was prepared leading up to the survival analysis, see Symbolix (2019).

2 Survival analysis

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.

2.1 Modelling

The model was fit on the set of 84 carcasses. We have used the exponential distribution to model survival rate. This model assumes a constant hazard throughout the "lifetime" of the carcass.

We started with a model of the form:

$$\text{Survival time} = \alpha + \beta \times \text{Species type} + \gamma \times \text{Month}$$

where species type is as set out in Table 1. Using an AIC selection method, we determined that:

- Month of year was a necessary factor
- Species type could be combined into the aggregated categories of: "bat + mouse", "eagle", "small bird + medium bird + bird of prey"

The final model coefficients, for the different categories, are displayed in Table 3.

Table 3: Final modelling coefficients for the mean scavenge rate (in days), plus their 95% confidence intervals.

Species type (aggregate)	Month	Mean	Lower	Upper
Eagle	Jan	465	160	1360
Eagle	Apr	292	98.8	865
Eagle	Jul	139	48.5	397
Eagle	Sep	844	290	2460
Small bird + medium bird + bird of prey	Jan	8.34	5.02	13.8
Small bird + medium bird + bird of prey	Apr	5.24	2.91	9.42
Small bird + medium bird + bird of prey	Jul	2.49	1.42	4.36
Small bird + medium bird + bird of prey	Sep	15.1	9.08	25.2
Bat + mouse	Jan	3.45	1.91	6.24
Bat + mouse	Apr	2.17	1.25	3.77
Bat + mouse	Jul	1.03	0.576	1.84
Bat + mouse	Sep	6.26	3.74	10.5

2.2 Species type differences

Figure 1 provides a comparison of the scavenger rates of different species types used in the trials. For clarity, we just plot the rates for species types for the January trials. The other months' trials have mean scavenger rates proportional to that of January.

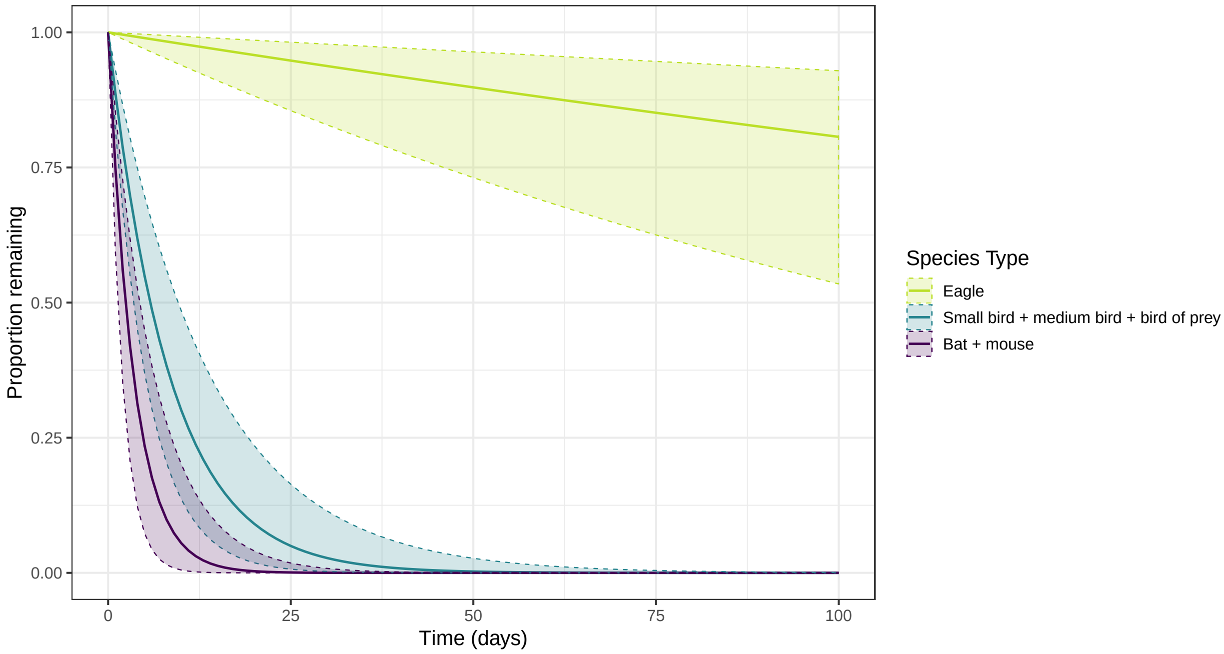

Figure 1: Comparative plot of scavenger rates of different species types (January only) with associated confidence intervals (shaded region).

During analysis, we found that:

- Separating bats and mice does not result in an improved model, via AIC selection. Therefore, we chose a model which aggregates them into a single category,
- Additionally, AIC selection favours combining small birds, medium birds and birds of prey.

We can see that bats and mice are scavenged the fastest, and eagles are scavenged the slowest. Other birds are scavenged somewhat faster than bats, but a lot slower than eagles.

For overall rates, aggregating over months, see Symbolix (2019).

2.3 Temporal differences

Via AIC selection, we found that incorporating month of year (of the trial start) resulted in a model with a better fit, compared to leaving the term out. Taking January as a baseline month, Table 4 describes the difference in scavenger rates between months, for eagles. September had relatively slower scavenger rate, while July had a relatively faster rate.

The values in Table 4 can be interpreted directly as multiplicative factors onto January's rate, for eagles.

Table 4: Multiplicative factors to scavenger rates, for different months.

Month	Factor	p-value
Apr	0.63	= 0.2
Jul	0.30	< 0.001
Sep	1.81	= 0.08

2.4 Probability of eagle carcasses remaining on the ground.

Table 5 shows the probability that an eagle carcass remains in-field (and observable) after 30 and 60 days, given the starting month of the trial.

Table 5: Probability of an eagle carcass remaining after 30 or 60 days.

statistic	Jan	Apr	Jul	Sep
Prob(carcass remains after 30 days)	0.94	0.90	0.81	0.97
Prob(carcass remains after 60 days)	0.88	0.81	0.65	0.93

3 Comparison with other sites

We are interested to see if scavenger behaviour is the same at Yaloak compared to other sites. We have available data from Portland Wind Farm. While we don't have wedge-tailed eagle scavenger data from Portland, we do have medium-sized bird and bat data.

We test the hypothesis that scavenger behaviour is similar at Portland compared to Yaloak, for medium sized birds and bats. Medium birds at Portland included the Ringnecked Parrot and Magpie, and medium birds at Yaloak included Crow, Magpie, and Quail. Bats were mostly White-striped Freetails.

The best fit model by AIC selection was one which differentiated between the two sites (and by species type). Therefore we cannot conclude that the scavenger behaviour is similar between sites. The Portland scavenger rate is not as fast as Yaloak's, by a factor of approximately 0.48.

References

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Appendix 3

Date	Turbine	Type	Species	Conservation Status	Proximity to Turbine (m)
16/07/2018	9	fs	cockatoo	secure	78
13/08/2018	13	bird	WTE	secure	110
10/09/2018	3	bat	Gould's wattled bat	secure	24
24/09/2018	13	fs	unknown	secure	54
24/09/2018	12	fs	WTE	secure	150
24/09/2018	12	bird	WTE	secure	90
8/10/2018	10	bat	Gould's wattled bat	secure	24
8/10/2018	10	bat	southern forest bat	secure	21
8/10/2018	8	bat	southern forest bat	secure	8
8/10/2018	4	fs	unknown	secure	46
22/10/2018	13	bat	Eastern falsistrelle	secure	16
22/10/2018	13	bat	Little forest bat	secure	18
22/10/2018	11	bat	Gould's wattled bat	secure	38
29/10/2018	7	bat	lesser long eared bat	secure	20
5/11/2018	7	bird	silvereye	secure	28
5/11/2018	12	bat	Little forest bat	secure	17
12/11/2018	13	bat	southern forest bat	secure	12
6/12/2018	11	bat	lesser long eared bat	secure	31
10/12/2018	12	bat	Eastern falsistrelle	secure	63
17/12/2018	8	bird	European goldfinch	secure	5
31/12/2018	6	bat	Gould's wattled bat	secure	32
31/12/2018	6	bat	Gould's wattled bat	secure	14
7/01/2019	12	bat	Gould's wattled bat	secure	41
7/01/2019	12	bat	Eastern falsistrelle	secure	22
7/01/2019	11	bat	WSFT	secure	46
10/01/2019	13	bat	Eastern falsistrelle	secure	26
14/01/2019	8	bat	unknown	secure	36
14/01/2019	7	bat	WSFT	secure	11
28/01/2019	14	bat	Gould's wattled bat	secure	17
28/01/2019	14	bat	unknown	secure	36
28/01/2019	3	bat	lesser long eared bat	secure	24
28/01/2019	10	bat	Gould's wattled bat	secure	16
28/01/2019	10	bat	WSFT	secure	13
28/01/2019	2	bat	Gould's wattled bat	secure	26
4/02/2019	10	bat	WSFT	secure	10
4/02/2019	14	bat	WSFT	secure	50
4/02/2019	11	bat	WSFT	secure	10
7/02/2019	4	bat	WSFT	secure	21
7/02/2019	5	bird	crested pigeon	secure	6
7/02/2019	7	bat	WSFT	secure	40

Date	Turbine	Type	Species	Conservation Status	Proximity to Turbine (m)
7/02/2019	11	bat	WSFT	secure	35
7/02/2019	13	bat	WSFT	secure	29
7/02/2019	13	bat	WSFT	secure	15
7/02/2019	13	bat	WSFT	secure	29
7/02/2019	14	bat	Gould’s wattled bat	secure	14
11/02/2019	14	bat	Gould’s wattled bat	secure	4
11/02/2019	3	fs	magpie	secure	50
11/02/2019	6	bat	Eastern falsistrelle	secure	15
19/02/2019	3	bat	WSFT	secure	39
25/02/2019	13	bat	Gould’s wattled bat	secure	2
25/02/2019	12	bat	large forest bat	secure	2
4/03/2019	7	bat	WSFT	secure	5
4/03/2019	7	bat	lesser long eared bat	secure	11
7/03/2019	6	bat	unidentifiable	secure	22
7/03/2019	5	bat	WSFT	secure	46
7/03/2019	10	bat	lesser long eared bat	secure	23
7/03/2019	10	bat	Gould’s wattled bat	secure	8
7/03/2019	11	bat	Eastern falsistrelle	secure	27
7/03/2019	14	bat	lesser long eared bat	secure	46
7/03/2019	13	bat	lesser long eared bat	secure	2
7/03/2019	13	bat	lesser long eared bat	secure	12
11/03/2019	3	bat	WSFT	secure	6
11/03/2019	11	bat	lesser long eared bat	secure	21
11/03/2019	11	bat	WSFT	secure	45
19/03/2019	4	bat	WSFT	secure	34
19/03/2019	3	bat	WSFT	secure	25
19/03/2019	5	bird	welcome swallow	secure	19
19/03/2019	5	bat	WSFT	secure	27
25/03/2019	6	bat	Gould’s wattled bat	secure	8
25/03/2019	13	bat	lesser long eared bat	secure	15
25/03/2019	13	bat	Eastern falsistrelle	secure	7
25/03/2019	13	bat	WSFT	secure	29
25/03/2019	14	bat	WSFT	secure	11
25/03/2019	2	bat	WSFT	secure	31
25/03/2019	2	bat	WSFT	secure	19
25/03/2019	2	bat	WSFT	secure	40
25/03/2019	11	bird	WTE (male, juvenile)	secure	137
4/04/2019	4	bat	Eastern falsistrelle	secure	34
16/04/2019	13	bat	lesser long eared bat	secure	9
16/04/2019	13	bat	large forest bat	secure	15
16/04/2019	13	bat	lesser long eared bat	secure	16
16/04/2019	3	bat	Eastern falsistrelle	secure	14
16/04/2019	7	bat	chocolate wattled bat	secure	35

Date	Turbine	Type	Species	Conservation Status	Proximity to Turbine (m)
16/04/2019	4	bat	WSFT	secure	15
16/04/2019	4	bat	lesser long eared bat	secure	7
8/10/2019	5	bat	Eastern falsistrelle	secure	22
23/10/2019	11	bat	lesser long eared bat	secure	38
5/11/2019	9	bat	southern forest bat	secure	32
19/11/2019	13	bat	southern forest bat	secure	10
19/11/2019	14	bat	lesser long eared bat	secure	48
19/11/2019	1	bat	Gould’s wattled bat	secure	54
3/12/2019	14	bat	southern forest bat	secure	30
3/12/2019	14	bat	Gould’s wattled bat	secure	42
6/12/2019	12	bat	WSFT	secure	57
10/01/2020	14	bat	Gould’s wattled bat	secure	29
10/01/2020	14	bat	WSFT	secure	20
10/01/2020	5	bat	WSFT	secure	17
7/02/2020	9	bat	small forest bat	secure	35
7/02/2020	12	bat	WSFT	secure	5
3/03/2020	1	bat	unknown	secure	35
3/03/2020	9	bat	WSFT	secure	43
3/03/2020	11	bat	LLE	secure	13
3/03/2020	13	bat	Eastern falsistrelle	secure	70
6/03/2020	1	bat	WSFT	secure	11
6/03/2020	5	bat	unknown	secure	33
6/03/2020	12	bat	LLE	secure	53
6/03/2020	13	bat	unknown	secure	11
6/03/2020	13	bat	LLE	secure	23
7/04/2020	4	bat	Eastern falsistrelle	secure	34
7/04/2020	4	bat	WSFT	secure	67
7/04/2020	6	bat	Gould’s wattled bat	secure	11
7/04/2020	5	bat	WSFT	secure	37
7/04/2020	9	bat	Eastern falsistrelle	secure	26
7/04/2020	10	bat	Unknown forest bat	secure	79
7/04/2020	13	bat	WSFT	secure	8
10/04/2020	2	bat	Gould’s wattled bat	secure	13
10/04/2020	5	bat	Unknown forest bat	secure	31
10/04/2020	9	bat	Gould’s wattled bat	secure	37
8/05/2020	7	bat	WSFT	secure	45
8/05/2020	6	bat	Gould’s wattled bat	secure	50
8/05/2020	13	bat	southern forest bat	secure	29
2/06/2020	3	bat	WSFT	secure	0
2/06/2020	6	bat	WSFT	secure	0
13/08/2019	7	bird	bronze wing pigeon	secure	4
27/08/2019	7	bird	bronze wing pigeon	secure	4
24/09/2019	10	bird	WTE	secure	53

Date	Turbine	Type	Species	Conservation Status	Proximity to Turbine (m)
8/10/2019	11	bird	Magpie	secure	23
19/11/2019	13	bird	WTE	secure	24
19/11/2019	13	bird	WTE	secure	68
3/12/2019	1	bird	unknown	secure	9
6/12/2019	10	bird	sparrow	secure	35
6/03/2020	1	bird	starling	secure	71
10/09/2019	4	fs	Magpie	secure	60
23/10/2019	12	fs	Magpie	secure	55
5/11/2019	14	fs	unknown	secure	33
6/12/2019	6	fs	unknown	secure	5
3/03/2020	9	fs	unknown	secure	37
6/03/2020	1	fs	cockatoo	secure	47
3/11/2020	10	bat	WSFT	secure	44
3/11/2020	14	bird	Brown Falcon	secure	41
3/11/2020	4	fs	magpie	secure	8
6/11/2020	7	bat	Gould's wattled bat	secure	16
6/11/2020	6	bird	Common bronzewing pigeon	secure	20
1/12/2020	5	bird	WTE	secure	35
4/12/2020	4	bird	Chestnut Teal	secure	15
5/01/2021	10	bat	Gould's wattled bat	secure	16
5/01/2021	14	bat	lesser long eared bat	secure	21
5/01/2021	11	bat	little forest bat	secure	32
8/01/2021	6	bird	WTE	secure	47
4/02/2021	5	bird	White-throated Needletail	threatened	47
4/02/2021	1	bat	Gould's wattled bat	secure	21
1/03/2021	14	bat	Gould's wattled bat	secure	32
1/03/2021	5	fs	nankeen kestrel	secure	69
4/03/2021	14	bat	southern forest bat	secure	24
4/03/2021	10	bat	WSFT	secure	3
4/03/2021	10	bat	Southern Forest Bat	secure	10
4/03/2021	10	bat	Southern Forest Bat	secure	16
4/03/2021	10	bat	chocolate wattled bat	secure	60
6/04/2021	9	bat	WSFT	secure	30
6/04/2021	9	bat	Gould's wattled bat	secure	28
6/04/2021	9	bat	Eastern Falsistrelle	secure	19
6/04/2021	13	bat	Large forest bat	secure	38
6/04/2021	14	bat	chocolate wattled bat	secure	6
6/04/2021	14	bat	Gould's wattled bat	secure	22
6/04/2021	8	bird	WTE	secure	38
6/04/2021	6	bat	Gould's wattled bat	secure	48
6/04/2021	4	bat	WSFT	secure	35
6/04/2021	3	bird	sparrow	secure	7

Date	Turbine	Type	Species	Conservation Status	Proximity to Turbine (m)
6/04/2021	2	fs	nankeen kestrel	secure	42
9/04/2021	9	bat	little forest bat	secure	11
9/04/2021	12	bat	lesser long eared bat	secure	31
9/04/2021	13	bat	little forest bat	secure	32
9/04/2021	7	bat	Gould's wattled bat	secure	19
9/04/2021	5	bat	WSFT	secure	51
9/04/2021	5	bat	Eastern Falsistrelle	secure	20
9/04/2021	1	bat	WSFT	secure	40
7/05/2021	1	bat	WSFT	secure	27
7/05/2021	2	bird	nankeen kestrel	secure	43
7/05/2021	3	bat	WSFT	secure	55
7/05/2021	11	bat	little forest bat	secure	9
7/05/2021	12	bat	little forest bat	secure	22
7/05/2021	13	bat	WSFT	secure	17
1/06/2021	7	bat	Gould's wattled bat	secure	22
1/06/2021	10	bird	WTE (J, m)	secure	56

Key:

WSFT – white striped freetail bat

WTE – wedge tailed eagle

fs – feather spot

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Appendix 4

Searcher Efficiency Trial Yaloak South Year 3

Date (2021)	Turbine	Handler	Search type	Substrate	Target	Target Type	Number	Distance	Found
9-Oct	1	luke	dog	hs	WSFT	bat	1	5	1
9-Oct	1	luke	dog	hs	pigeon	bird	2	20	1
9-Oct	2	luke	dog	sg	magpie	bird	3	15	1
9-Oct	3	luke	dog	sg	brown falcon	bird	4	45	1
9-Oct	3	luke	dog	hs	WSFT	bat	5	10	1
9-Oct	4	luke	dog	hs	WSFT	bat	6	10	1
9-Oct	4	luke	dog	mg	brown falcon	bird	7	60	1
9-Oct	5	luke	dog	mg	WSFT	bat	8	25	0
9-Oct	6	luke	dog	hs	nankeen kestrel	bird	9	22	1
9-Oct	6	luke	dog	hs	WSFT	bat	10	2	1
9-Oct	6	luke	dog	hs	magpie	bird	11	15	1
9-Oct	7	luke	dog	sg	WSFT	bat	12	10	1
9-Oct	8	luke	dog	hs	peregrine falcon	bird	13	20	1
9-Oct	8	luke	dog	hs	WSFT	bat	14	15	1
9-Oct	9	luke	dog	mg	nankeen kestrel	bird	15	45	1
9-Oct	9	luke	dog	sg	pigeon	bird	16	30	1
9-Oct	10	luke	dog	mg	gould's wattled bat	bat	17	35	1
9-Oct	10	luke	dog	mg	cockatoo	bird	18	55	1
9-Oct	11	luke	dog	lg	peregrine falcon	bird	19	50	1
9-Oct	12	luke	dog	mg	crow	bird	20	30	1
9-Oct	12	luke	dog	mg	WSFT	bat	21	15	1
9-Oct	12	luke	dog	sg	WSFT	bat	22	25	1
9-Oct	13	luke	dog	sg	brown falcon	bird	23	20	1
9-Oct	13	luke	dog	mg	nankeen kestrel	bird	24	45	1
9-Oct	14	luke	dog	sg	WSFT	bat	25	15	1

Appendix 5

Monte Carlo Simulation

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. We used a Monte-Carlo simulation to achieve this.

Monte Carlo simulations are a mathematical technique used to estimate the possible outcomes of an uncertain event. It is a tool used to improve decision making under uncertain conditions and provides a number of advantages over predictive models such as the ability to conduct sensitivity analysis. Sensitivity analysis allows the influence of various inputs to be understood (such as detection and scavenging rates). Unlike traditional forecasting models, Monte Carlo simulations predict a set of outcomes based on an estimated range of values, rather than a set of fixed input values and builds a model of possible results using a probability distribution.

The analysis uses survey data to estimate the average time to scavenge loss and searcher efficiency (and related confidence intervals). The algorithm then simulates different numbers of virtual mortalities. We can 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 (Huso (2011), 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).

Adapted from Symbolix mortality estimate reports.