Report

Post Construction Bird and Bat Monitoring Results, Year 1: July 2018 to June 2019

Yaloak South Wind Farm, Victoria

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for

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ELMOBY ECOLOGY

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 first-year of the post construction monitoring program (July 2018 – June 2019).

Methods

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

- Scavenger Trials (section 2.2)
- Observer Efficiency (section 2.3)
- Post construction carcass searches (section 2.4)

Data Analysis

Statistical analysis for the year one 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 90% with a confidence interval of [84%,94%] was applied.

Scavenger Efficiency

There was evidence of differences between the scavenging rate of bats, 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 3.4 days with a 95% confidence it is between [2.4, 4.9] days.
- Birds (not including eagles) is 8.3 days with a 95% confidence it is between [5.9, 11.6] days.
- Eagles is 394.8 days with a 95% confidence it is between [148.2,1057.9] days.

Mortality Detection Surveys

During the first year of surveys a total of 80 finds were recorded during formal surveys, 73 bats and 7 birds. This was comprised of 5 different species of birds, 2 feather spots unable to be identified to species level and 8 species of bats. An additional 5 birds were found outside of the 60m survey area, 4 wedge tail eagles and 1 cockatoo. All species found are considered secure in their range.

On average we estimate the number of bats impacted during the period of this report was 188 with a 95% confidence that fewer than 231 individuals were lost. During the same period, the average impact estimate for birds is 17 with a 95% confidence that fewer than 26 individuals were lost. We expect that all wedge tail eagle carcasses were found during the survey period and that the total number of eagles impacted was 4.

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1 INTRODUCTION

1.1 Background

The purpose of this report is to summarise the findings of the first year 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 10007321 allowing for the collection and storage of birds of bats found dead within the wind farm site and along road sides 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 in 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 across Victoria 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 effort.

2.2 Carcass Persistence Trials

Persistence trials were undertaken 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.

Four scavenger trials were conducted using a collective total of 89 carcasses, although some data was lost due to camera difficulties, giving a final total number used for analysis of 84 observations (table 1). Motion cameras were used to try and estimate an exact time of removal. This method was complicated by the interference from shadow flickering from the turbines and the presence of livestock within the area which caused the camera data storage to fill quickly. Cameras were switched to take photos hourly rather than on sensor, thus with the exception of the September trial, determining the type of scavenger was not possible.

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

Species Type	Sep (2018)	Jan (2019)	Apr (2019)	Jul (2019)
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

Monitoring of carcasses occurred for 31 days except for the eagles 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 trial, however, following the discovery of eagles as the primary scavengers of other eagles, eagle carcasses were placed greater than 200m from the turbine base to reduce the risk of collisions for subsequent trials (Figure 2).

Figure 2: Scavenging of eagle carcasses by other eagles meant the increased risk of collision of placing eagles within close proximity to a turbine was too great and the study design was altered to reduce this risk

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 appendix 2).

2.3 Searcher Efficiency

Searcher efficiency trials are conducted to determine the likelihood of the survey team detecting a carcass during surveys if one is present. 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 in the present of 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. Two trials conducted at Yaloak South were compared with 4 other trials conducted since 2016 (Mt Mercer, Mortons Lane and Mt Gellibrand) and analysed for differences using binomial regression and stepwise AIC selection.

2.4 Carcass Searches

Carcasses surveys were conducted by trained detection dogs and their handlers weekly from July 2018 until April 2019 at every turbine to a radius of 60m with an additional "pulse" survey scheduled for the high risk period for the detection of bats. Pulse surveys occurred 3 days after the scheduled survey in all months between November and May meaning at least 5 surveys per month at every turbine were conducted during this time. From May 2019, fortnightly searches commenced rather than weekly in accordance with the updated Bat and Avifauna Management Plan and as agreed with the DELWP. Full details of survey methodology can be found in section 3 of the Bat and Avifauna Management Plan for Yaloak South Wind Farm: Volume 2 Implementation Plan.

2.4.1 Data Analysis

The mortality estimation is done via two Monte-Carlo simulations, one for bats and one for birds. Each used 25000 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. Full details of the analysis can be found in appendix 1.

3 RESULTS

3.1 Observer Efficiency

Two searcher efficiency trials were carried out at Yaloak South Wind Farm and an additional 4 trials were conducted on the same dog/ handler teams at three other wind farms during or within the previous two years. There was no evidence that searcher efficiency differed between the sites nor 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 90% with a 95% confidence interval of [84%, 94%].

Table 2 Detection efficiency combined

Variable	Combined estimate
Number found	135
Number placed	150
Mean detectability proportion	0.9
Detectability lower bound (95% confidence interval)	0.84
Detectability upper bound (95% confidence interval)	0.94

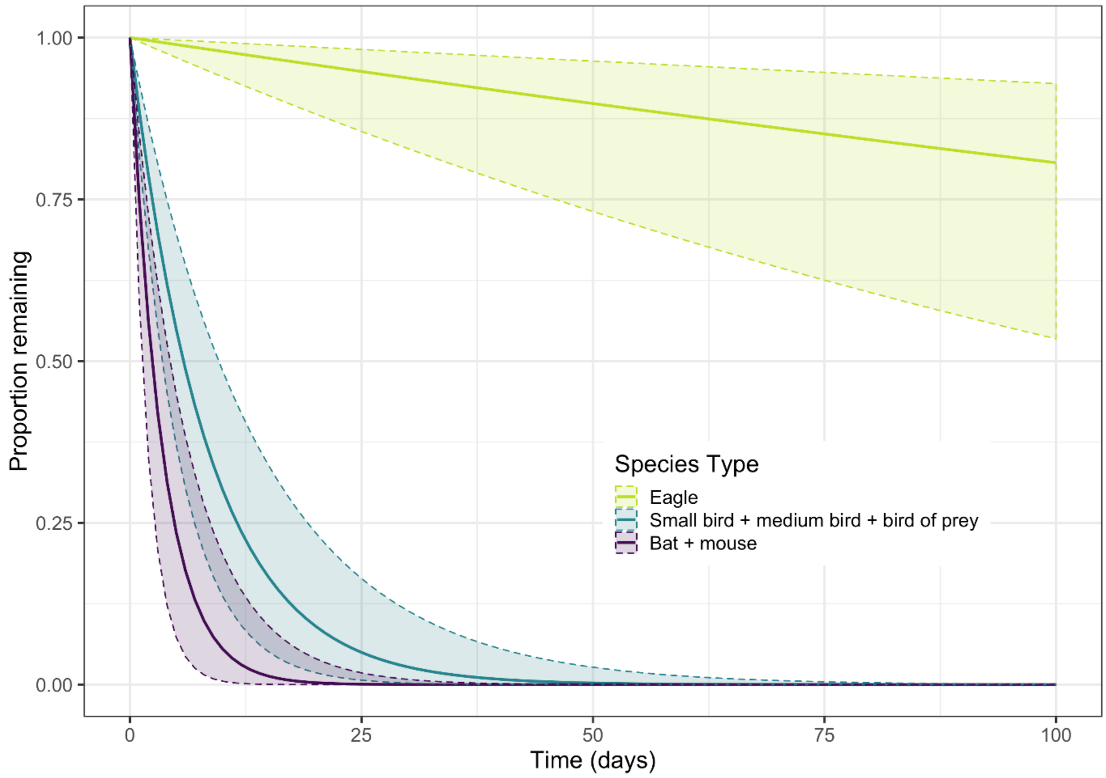
3.2 Scavenger Trials

Four scavenger efficiency trials were conducted in each season of the first year[1] with a total of 84 carcasses with complete data used for analysis. There were 14 carcasses remaining at the end of the trial, 12 of which were eagles. During analysis it was found that separating bats and mice did not improve model selection, and thus they were combined as an aggregate. It was also found that the model favoured combining small birds, medium birds and birds of prey (excluding eagles) into a single category. Thus three different scavenging rates were determined.

Survival curves fitted to the scavenge data shows a difference between the scavenge rate of bats (and mice), birds and eagles with the assumption that all scavengers are “perfect” (figure 3). The average time for loss of bats and mice is 3.4 days with a 95% confidence interval of [2.4, 4.9]. The average time for birds (not including eagles) is 8.3 days with a 95% confidence interval of [5.9, 11.6]. For eagles, the mean time to total loss by scavengers is 394.8 days, with a 95% confidence interval of [148.2, 1051.9]. Total loss refers to a loss of all evidence including feather spots.

[1] Scavenger trials commenced in September 2018 with the 4th (winter) trial commencing in July 2019, just outside the first year of monitoring.

Figure 3 Survival curve showing difference persistence for eagles, birds and bats.



The probability of an eagle remaining in the field for a given length of time was calculated and it was found that there was some seasonal variability in persistence time (Table 4). Incorporating season as a factor resulted in a slightly better fitting model for eagles with the July trial showing a slightly faster scavenge rate and the September trial shows a slightly slower rate (relative to January).

Table 4 Probability of an Eagle carcass remaining after 30 or 60 days

Statistic	Sep	Jan	Apr	Jul
Probability that the carcass remains after 30 days	0.97	0.94	0.90	0.81
Probability that the carcass remains after 60 days	0.93	0.88	0.81	0.65

3.3 Carcass Searches

Carcass searches were carried out between July 2018 and June 2019 at every turbine. In total 744 turbine searches were carried at the 14 turbines (Table 5). Occasionally a turbine was not surveyed due to the presence of active lambing in 2018[2] or unsafe access and appropriate correction factors where considered when providing estimates. For a full list of assumptions please see appendix 2.

Table 5 Carcass Survey Summary per month

	Date	Number of surveys
2018	Jul	70
	Aug	46
	Sep	46
	Oct	83
	Nov	69
	Dec	84
2019	Jan	69
	Feb	69
	Mar	70
	Apr	68
	May	42
	Jun	28[3]

A total of 73 bats and 7 birds or feather spots were found during routine mortality searches (Table 7). An additional 5 carcasses were found by dogs outside the survey area. This included the 4 wedge tail eagles found on site during the first year (Table 6).

[2] A protocol has been agreed to between Yaloak Estate and Pacific Hydro and endorsed by the Moorabool Shire Council that ensures active lambing will not occur in paddocks with turbines in the future.

[3] The lower number of surveys recorded in June 2019 is due to the move from weekly to fortnightly surveys.

Table 6 Summary of incidental finds outside 60m survey area

Species	Distance from Turbine	Turbine	Month	Condition
Cockatoo	78	9	Jul 2018	Feather spot
Wedge Tail Eagle	110	13	Aug 2018	Complete
Wedge Tail Eagle	150	12	Sep 2018	Scavenged
Wedge Tail Eagle	90	12	Sep 2018	Complete
Wedge Tail Eagle	137	11	Mar 2019	Complete

Table 7 Summary of species found during carcass searches

	Species	Count
bats	Chocolate wattled bat	1
	Eastern falsistrelle	9
	Gould's wattled bat	14
	White striped freetail bat	26
	Large forest bat	2
	Lesser long eared bat	13
	Little forest bat	2
	Southern forest bat	3
	Unidentifiable bat	3
birds	Welcome swallow	1
	Crested pigeon	1
	Australian magpie	1
	Silvereye	1
	European goldfinch	1
	Unidentifiable bird	2

3.3.1 Mortality estimation for bats

During the survey period, a total of 73 bats were found at Yaloak South with 75% of finds detected during standard surveys, and 25% during pulse surveys. Finds were restricted to September to April, with more than half found during the 2 month period of February and March. The resulting estimate, taking into consideration scavenger removal and searcher efficiency, is a mean loss of 188 bats for the year. Based on the detected carcasses we can be 95% confidence that fewer than 231 individual bats were lost (Figure 4).

3.3.2 Mortality estimation for birds

During the survey period, a total of 7 birds were found at Yaloak South Wind Farm. The resulting estimate taking into consideration scavenger removal and searcher efficiency is a mean loss of 17 birds for the period. This estimation also includes correction factors for a 60m search area and is thus accounting for birds found outside the survey area (Hull and Muir 2010). Based on the detected carcasses we can be 95% confidence that fewer than 26 individual birds were lost (Figure 5).

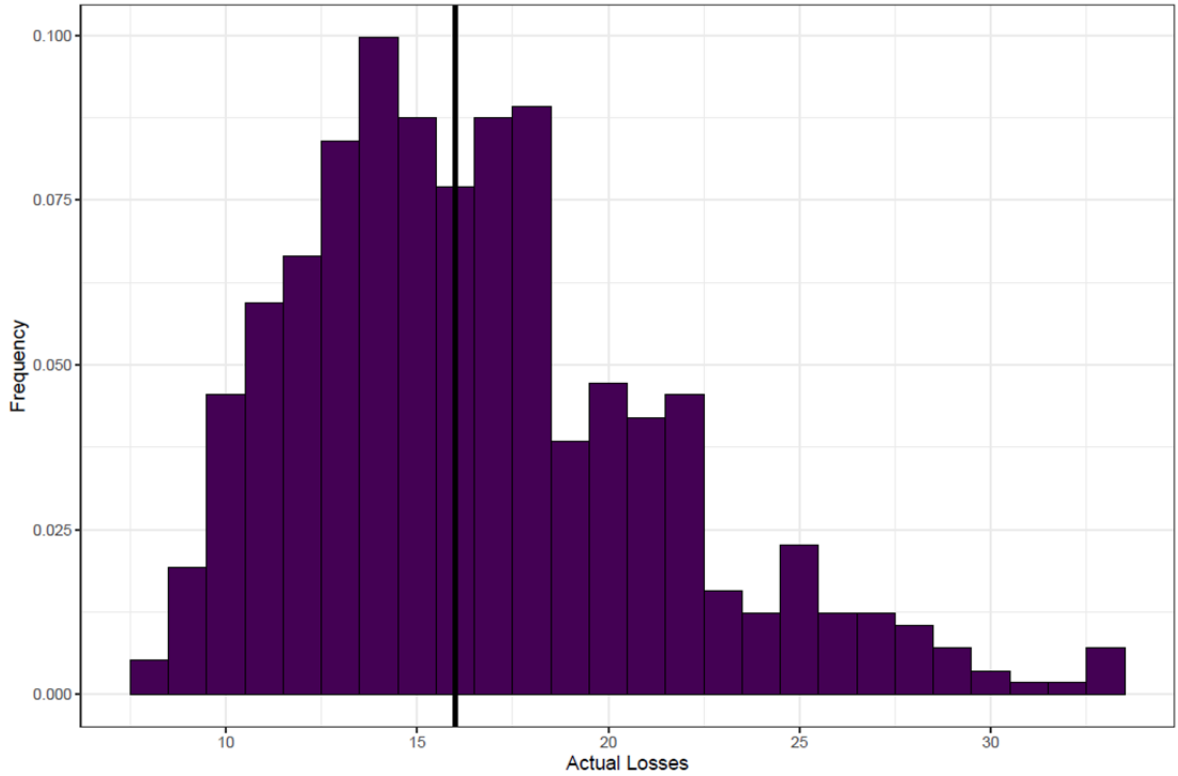


Figure 4. Empirical distribution of bat losses at Yaloak South Wind Farm

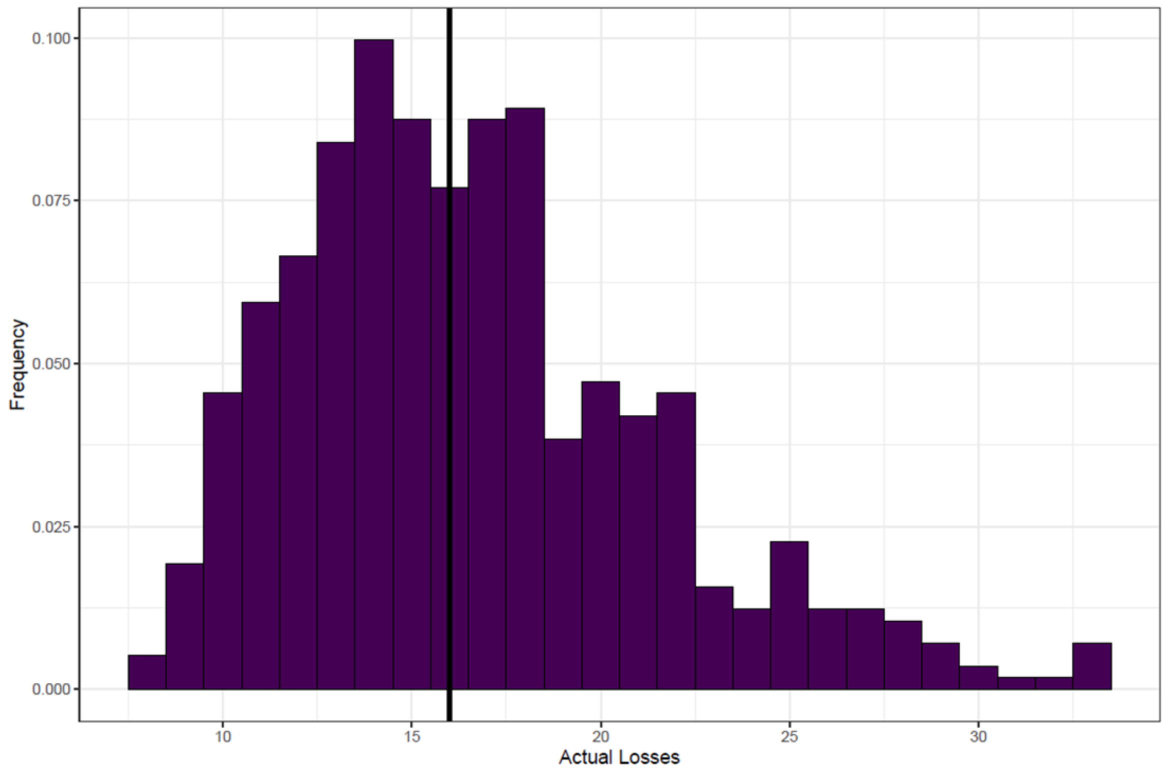


Figure 5. Empirical distribution of bird losses at Yaloak South Wind Farm

3.3.3 Mortality estimation for eagles

No eagles were found as part of routine turbine surveys, however 4 eagles were detected by the dog teams outside of the allocated survey area and most likely victims of turbine collision. 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. It is also possible that the second of the two eagles found at turbine 12 in September 2018 was attracted to the site by the first eagle killed as evidence of scavenging on one of the carcasses was likely to have been caused by other eagles.

4 DISCUSSION

4.1 Searcher Efficiency

Results from several trials indicated that combined searcher efficiency for detection of both birds and bats is 90% [84%, 94%] and 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 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 Scavenger Efficiency

It was demonstrated that the persistence of carcasses in the landscape does vary by size and type, 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, we demonstrated that the persistence of wedge tail eagles is much greater than that of other birds or bats, with all carcasses persisting for longer than 30 days and that on average there was still an 80% probability of a carcass persisting past 60 days.

Scavenging rates for wedge tail eagles may be different to other birds due to the predatory nature of this species. Evidence of foxes approaching the carcass was available from the motion cameras during the September study, however the foxes did not attempt to scavenge and did not remain near the carcass for long. It was shown that eagles and later crows were the primary scavengers of eagle carcasses. The persistence of eagle carcasses suggests that studies aimed at detecting eagle impacts would benefit from searching more turbines less often rather than increasing the survey interval more frequently than monthly.

The trial was predetermined to last for 30 days to provide an indicative indication of persistence over a monthly search interval. However, data on eagle persistence was collected opportunistically past 60 days, and up to 7 months for some specimens, with three eagle carcasses remaining in the field at the completion of this report. Thus, the best fit estimation of removal rate for eagles using survival analysis shows a curve which can extend past the duration of the study (Figure 3). However, confidence around the mean persistence for eagle carcasses is reduced over time and thus the probability of persistence over 30 and 60 days (Table 4) is more meaningful in the context of wind farm mortality estimation.

4.3 Carcass Searches

Overall mortality estimates for birds and bats at Yaloak South Wind Farm are 95% confident that no more than 231 bats and 26 birds were impacted during the first year of monitoring. The average number of bats likely to be impacted per turbine per year is 13.5, with a 95% confidence that less than 16.5 bats will be impacted. This figure does not take into consideration the temporal patterns of bats and assumes that bats have an equal chance of being impacted throughout the year. More than half of all bats detected during surveys were found in February and March and no bats were found from May through to August, so it is likely that this figure over estimates the true number of bats impacted.

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 land scapes. 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.

The average number of birds likely to be impacted per turbine per year is 1.2 birds, with a 95% confidence that less than 1.9 birds per turbine will be impacted. This figure takes into consideration the 60m search area, searcher efficiency and scavenging rates and is likely a good estimation of the true impact. National averages for Australia have not been estimated, but a summary of 32 wind farms in Canada found an average of 8.2 ± 1.4 birds per turbine per year were impacted which is more than 6 times the rate recorded for Yaloak South Wind Farm (Zimmerling et al. 2013). Previous experience suggests that the reported range of bird impacts at Yaloak South Wind Farm is typical of wind farms in South Eastern Australia.

4.4 Significant Impacts

Events considered a significant impact are outlined in section 3, Volume 1 of the endorsed Bat and Avifauna Management Plan for Yaloak South Wind Farm. No species listed as threatened or migratory under the Commonwealth EPBC Act, listed as threatened under Victoria's FFG Act or species listed as vulnerable, endangered or critically endangered under the Advisory list of threatened vertebrate fauna in Victoria (DSE 2013) were found during carcass searches at Yaloak South Wind Farm.

Wedge tail eagles are not considered to be under any level of threat on the Australian mainland, however the level of impact presented to individuals at Yaloak South Wind Farm is a primary consideration of the post construction mortality monitoring program. Modelled projections of up to 6.7 Wedge Tail Eagles was considered to pose no threat to the species' population[4]. The 4 eagles impacted in the first year of operation is less than this modelled projection and is therefore considered to have a negligible impact to the population of eagles.

[4] 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 Searcher Efficiency

Searcher efficiency trials have demonstrated high detection for both birds and bats. Due to the consistent high detection and number of trials already been conducted on the dog and handler teams, it is recommended that only 1 additional trial is required for year 2 of the study to ensure levels are maintained. However, due to requirements of the BAMP a further two trials will be undertaken.

5.2 Scavenger Efficiency

The scavenger trials at Yaloak South Wind Farm have been completed to a high standard and provides insights into the different scavenging rates of different types of carcasses. It is recommended that the information obtained from Yaloak South Wind Farm be prepared into a scientific summary and submitted to a peer reviewed journal for publication. This study provides valuable insights and information into the different rates of scavenging of different carcasses and would be a useful addition to the citable literature.

5.3 Mortality Survey

The low number of bird impacts at Yaloak South Wind Farm suggests that monthly searching outside of bat season is an adequate search interval for bird detection, particularly where eagles are the primary species of interest. The pulse search effort employed for the detection of bats from October through to April is justified to increase the certainty around bat impacts due to the high scavenging rates of bats.

6. REFERENCES

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

Mathews, F., M. Swindells, R. Goodhead, T. A. August, P. Hardman, D. M. Linton, and D. J. Hosken. 2013. Effectiveness of search dogs compared with human observers in locating bat carcasses at wind-turbine sites: A blinded randomized trial. Wildlife Society Bulletin **37**:34-40.

Zimmerling, J. R., A. C. Pomeroy, M. V. d'Entremont, and C. M. Francis. 2013. Canadian Estimate of Bird Mortality Due to Collisions and Direct Habitat Loss Associated with Wind Turbine Developments. Avian Conservation and Ecology **8**.

7. APPENDIX

1. Eagle carcasses placed during scavenger trial
2. Symbolix Report Yaloak Wind Farm Mortality Estimate Year 1
3. Symbolix Report Eagle Scavenger Trial Analysis

Appendix 1

The table below summarises the eagle carcasses used as part of the scavenger trials at Yaloak South Wind Farm. Carcasses were monitored daily (using cameras) for 2 months and then weekly using dogs for up to 4 months. Opportunistic detection was used after this time as eagles were outside the standard search area (to prevent further risk to scavenging birds). Survival analysis accounts for complete loss (including loss of feather spots) and thus an interval of removal is taken into consideration. Thus, in some instances, the last check still revealed evidence of the carcass.

Persistence of Wedge Tail Eagles (showing gender m/f)					
species	turbine	Date deployed	Last checked/ Gone	Condition	Length in study
WTE (m)	12	20/9/18	18/6/19	Feathers remaining	9 months
WTE (f)	2	20/9/18	18/6/19	Bones and feathers remaining	9 months
WTE (f)	10	20/9/18	7/1/19	Removed	3 months
WTE (m)	6	20/9/18	29/4/19	Feather spot remaining	7 months
WTE (f)	8	20/9/18	30/10/19	Removed	40 days
WTE (m)	4	7/1/19	15/4/19	Hay deployed over remains, not evident after that	3 months
WTE (m)	7	7/1/19	14/5/19	Bones and feathers remaining	4 months
WTE (f)	13	7/1/19	14/5/19	Bones and feathers remaining	4 months
WTE (m)	3	30/4/19	Still present (Sep 2019)	Complete carcass	
WTE (f)	7	30/4/19	18/6/19	Feather spot remaining	1.5 months
WTE (f)	10	30/4/19	12/7/2019	removed	2.5 months
WTE (f)	13	30/4/19	14/5/19	Feather spot remaining	2 weeks
WTE (f)	8	2/7/19	Still present (Sep 2019)	Complete carcass	
WTE (f)	10	2/7/19	Still present (Sep 2019))	Complete carcass	
WTE (f)	11	2/7/19	13/8/19	Feather spot remains	41 days

Appendix 2

Yaloak South Wind Farm Mortality Estimate - Year 1

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

This report outlines an analysis of the mortality data collected at Yaloak South Wind Farm from 2018-07-02 to 2019-06-18. The analysis is broken into the three related components below:

- Searcher efficiency / detectability
  - Trials were conducted at Yaloak South in April 2019
    - 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 starting on: 2018-09-20, 2019-01-08, 2019-04-30, 2019-07-02
- Mortality estimates - based on monthly surveys at all 14 turbines, from 2018-07-02 to 2019-06-18

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

The data analysed was collected, verified and provided to us from Elmoby Ecology[1].

Data cleaning

Data cleaning steps are briefly outlined in this section.

Survey file

- We removed surveys which were scheduled, but not held (e.g. due to lambing).
- Two duplicated surveys were fixed.

[1] `YSWF Survey Data year 1.xlsx`, `Yaloak scav trial complete.xlsx`, `detection combined.xlsx`

Carcass finds file

- We flagged carcasses which were not found in the formal search area.

Searcher efficiency file

No cleaning necessary.

Scavenger trial file

The file was converted to a tidy "flat" format using the following steps:

- We used the conservative estimate of noon on the day of the trial for the trial start time. We know noon is the latest that carcasses could possibly be placed, as all carcasses were placed in the morning of the trial day. This is conservative because it results in a faster scavenger rate estimate, and so a higher estimate of total mortality. If this resulted in a negative time-to-observation, the trial start time was set as an hour prior to the observation.
- If the exact time was available for the "last seen" and "gone" times, it was used, else we arbitrarily set it as midnight on the provided date.
- We removed carcasses for which data was not available (corrupted camera files).
- We classed anything still detectable by the canine searcher as "not scavenged", including feather spots.
- Species names were consolidated.
- A couple of miscoded dates were fixed.

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 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), F. 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

Six searcher efficiency trials were held (2019-04-15) at Yaloak South. The data provided for this analysis included the Yaloak South trial and data from three other Victorian Sites (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 regression) 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 90%, with a 95% confidence interval of [84%, 94%].

Table 1: Detection efficiency combined.

Variable	Combined estimate
Number found	135
Number placed	150
Mean detectability proportion	0.9
Detectability lower bound (95% confidence interval)	0.84
Detectability upper bound (95% confidence interval)	0.94

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.

Based on these surveys there is evidence (via AIC) of a difference in scavenger rates between bats, eagles, and other birds. Therefore, in our final analysis we separate them. There was also evidence that scavenger rates differ in different months. In particular, the July trial's mean time to scavenge was the lowest, and the September trial's mean time to scavenge was the highest.

To determine an annual mortality rate we wish to encompass this variability so have combined the seasons into an annual rate and a standard error (the standard error accounts for the seasonal variation).

Figure 1 shows a survival curve fitted to cohorts of bat eagles, and other birds. All data was collected at the Yaloak South Wind Farm. The survival curves (solid lines) show the estimated proportion of the sets remaining at any given time. The shaded portions are the 95% confidence intervals on the estimates. For example, we see that we expect around 1% to 13% of bat carcasses to remain after ten days with the expectation being around 5%.

Under these assumptions, for bats, the mean time to total loss via scavenge is 3.4 days, with a 95% confidence window of [2.4, 4.9] days. For birds (not including eagles), the mean time to total loss via scavenge is 8.3 days, with a 95% confidence window of [5.9, 11.6] days. For eagles, the mean time to total loss via scavenge is 394.8 days, with a 95% confidence window of [148.2, 1051.9] days.

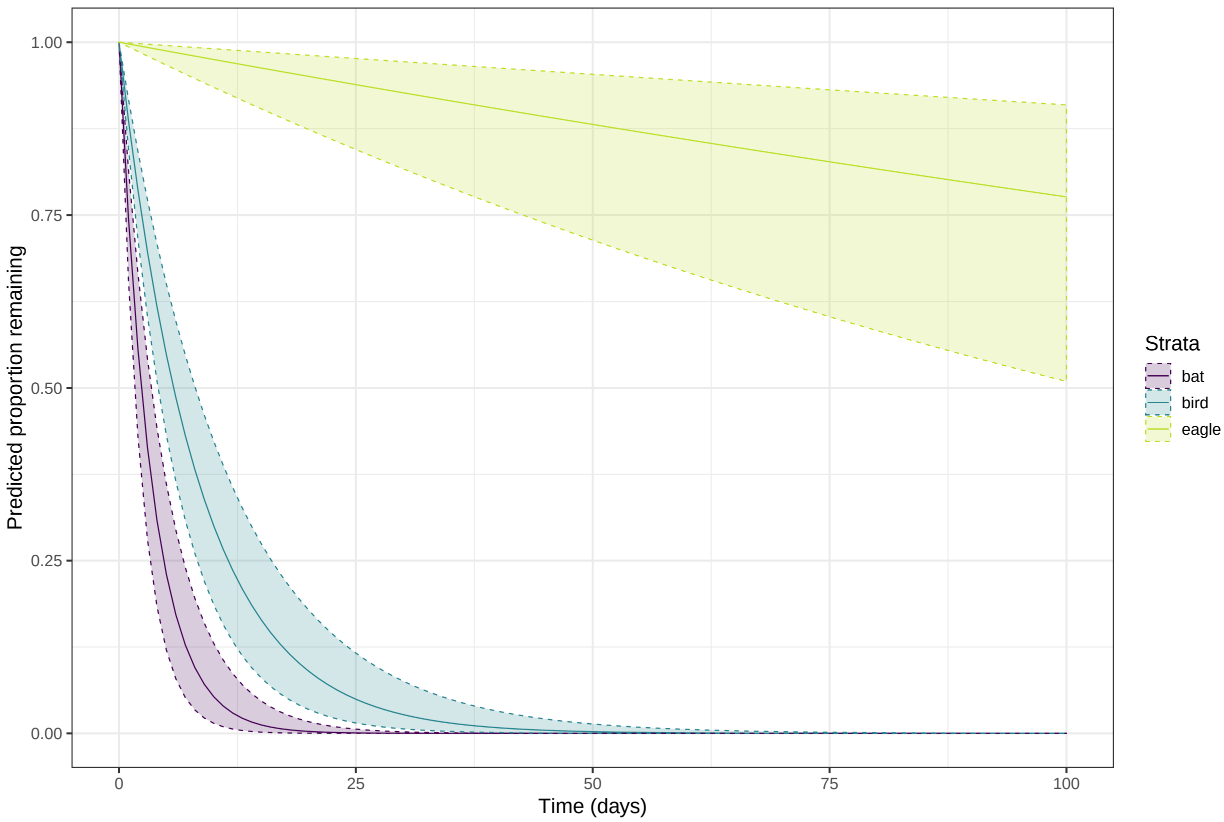


Figure 1: Combined survival curves for birds (not eagles), eagles, bats, with 95% confidence interval shaded.

When taking the bird mortality estimate, we have used the bird scavenger rate only (as we didn't find any eagles in formal surveys anyway). For more information on Yaloak South scavenger rate, see Symbolix (2019).

Other scavenger patterns

There are three general types of scavenger behaviour:

- "perfect"
- "olfactory"; and
- "visual"

These names are classifiers only, and not necessarily accurate descriptions of the actual processes employed by the scavenger. A "perfect" scavenger will find the carcass with constant efficiency, irrespective of the amount of time it has lain on the ground. "Visual" scavengers are more efficient in the earlier period post-mortem, and are less likely to find a carcass the longer it has lain there. "Olfactory" scavengers are the opposite of "visual" scavengers. They require the carcass to lie for some period, before their efficiency of detection increases.

We have focused on the mean loss rate, and not the shape. This means that we have assumed all scavengers to be "perfect", which is the middle of the two other types.

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. All fourteen turbines were surveyed five times each month until May when the frequency was reduced with DELWP's consent. All were surveyed out to a radius of 60 metres.

Table 2: Number of surveys per month.

Date	Number of surveys
2018 Jul	70
2018 Aug	46
2018 Sep	46
2018 Oct	83
2018 Nov	69
2018 Dec	84
2019 Jan	69
2019 Feb	69
2019 Mar	70
2019 Apr	68
2019 May	42
2019 Jun	28

Mortality estimate - year one

Mortality estimation – methodology

With estimates for scavenge loss and searcher efficiency we then converted the number of bat and bird carcasses detected into an estimate of overall mortality at Yaloak South Wind Farm from 2018-06-02 (we allow for collisions to occur up to a month prior to the first survey) to 2019-06-18.

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 (2018-07-02) and until the final surveyed date (2019-06-18).
- 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 exponential scavenge shape ("perfect" scavengers).
- 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 – 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 61% for birds, and 95% 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 in formal surveys, per species, are summarised in Table 3.

Table 3: Carcasses found during formal surveys in the first year of surveying.

Species	Bat	Bird	Feather Spot
chocolate wattled bat	1	0	0
crested pigeon	0	1	0
eastern falsistrelle	9	0	0
european goldfinch	0	1	0
goulds wattled bat	14	0	0
large forest bat	2	0	0
lesser long eared bat	13	0	0
little forest bat	2	0	0
magpie	0	0	1
silvereye	0	1	0
southern forest bat	3	0	0
unknown - bat	3	0	0
unknown - bird	0	0	2
welcome swallow	0	1	0
white striped freetail	26	0	0

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
cockatoo	2018-07-16
wte	2018-08-13
wte	2018-09-24
wte	2018-09-24
wte	2019-03-25

Bat mortality estimate – results

During the first year of surveys a total of 73 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 187 and a median of 186 bats lost on site over the twelve months.

Table 5 and Figure 2 display the percentiles of the distribution, to show the confidence interval in this average.

Based on the detected carcasses and measured detectability and scavenge rate, we expect that there was a total site loss of around 187 bats over the survey period, and are 95% confident that fewer than 232 individuals were lost.

Table 5: Percentiles of estimated total bat losses over the survey period.

0%	50% (median)	90%	95%	99%	99.9%
130	186	222	232	254	263

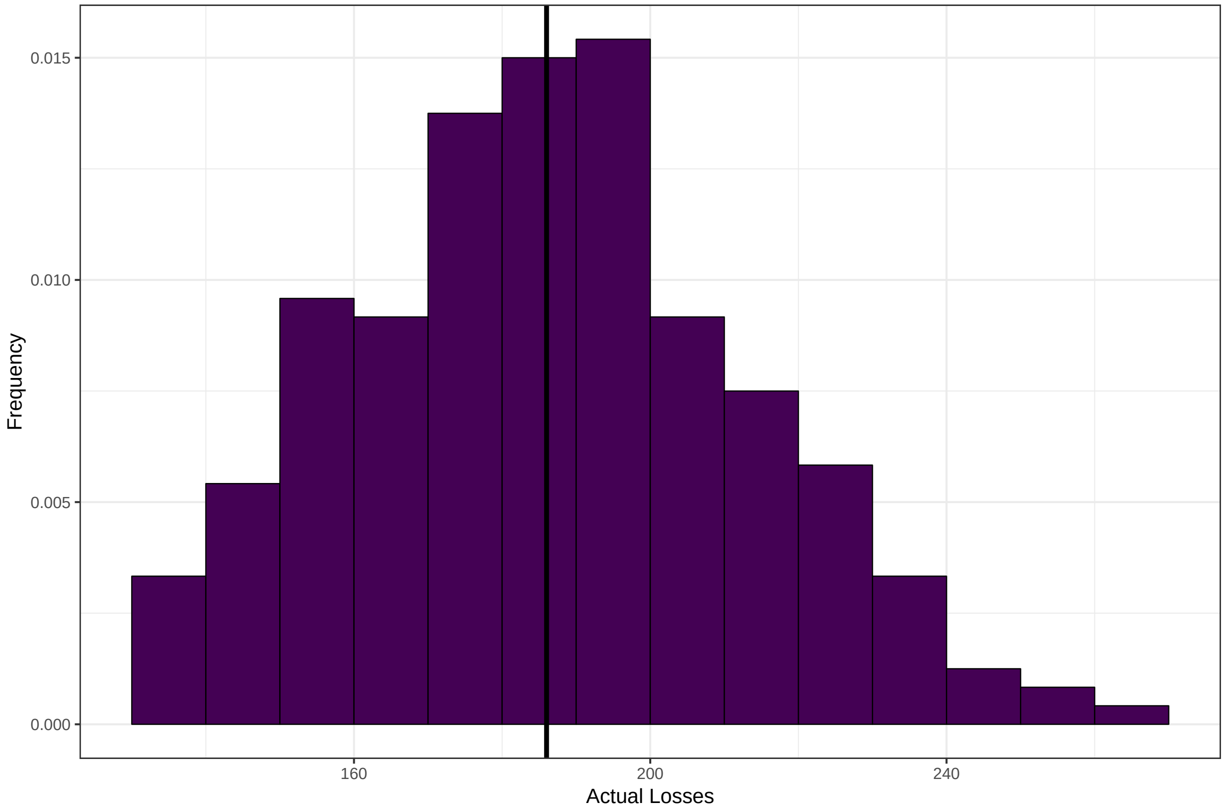


Figure 2: Histogram of the total losses distribution (bats), given 73 were detected on-site. The black solid line shows the median.

Bird mortality estimate - results

During the first year of surveys a total of 7 birds 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 17 and a median of 16 birds lost on site over the twelve months.

Table 6 and Figure 3 display the percentiles of the distribution, to show the confidence interval in this average.

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 17 birds over the survey period, and are 95% confident that fewer than 27 individuals were lost.

Table 6: Percentiles of estimated total bird losses over the two years of survey period.

0%	50% (median)	90%	95%	99%	99.9%
7	16	24	27	32	35

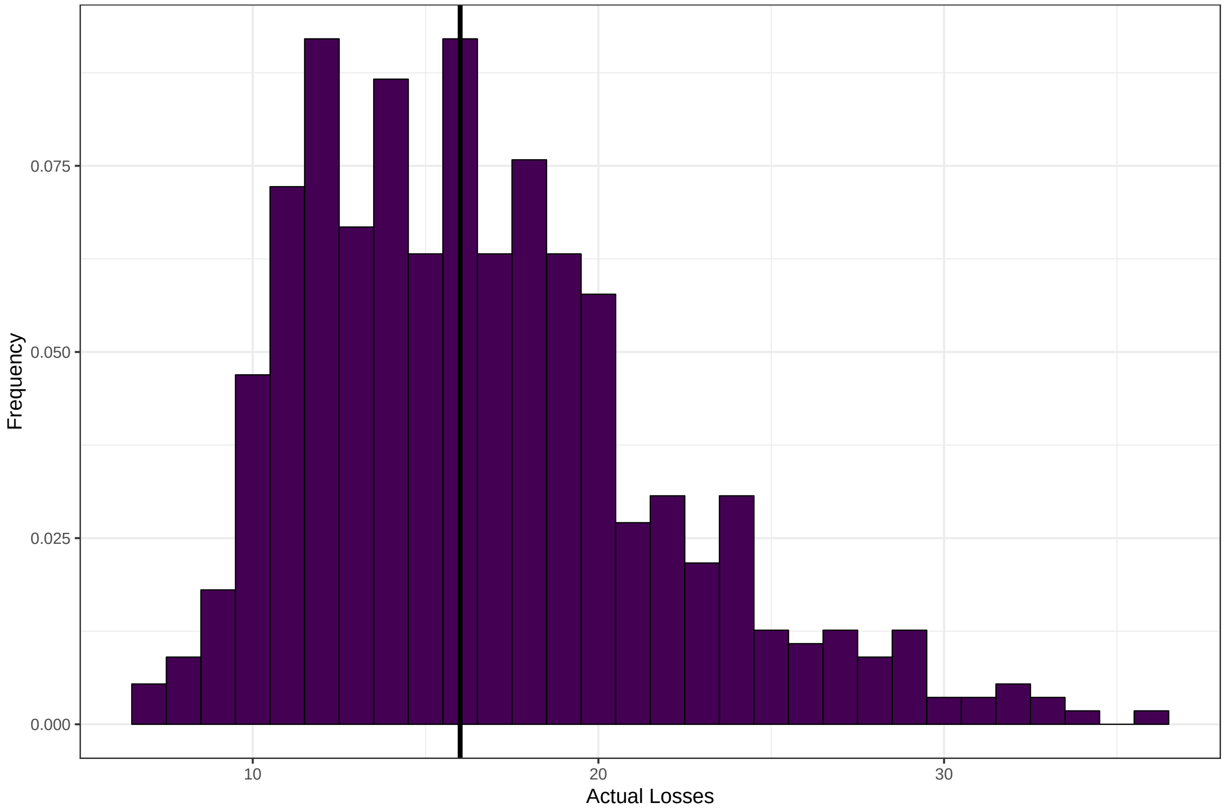


Figure 3: Histogram of the total losses distribution (birds), given 7 were detected on-site. The black solid line shows the median.

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, and we assumed that bats 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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Symbolix. 2019. “Eagle Scavenger Trial Analysis.” Symbolix.

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 South 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 South 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.

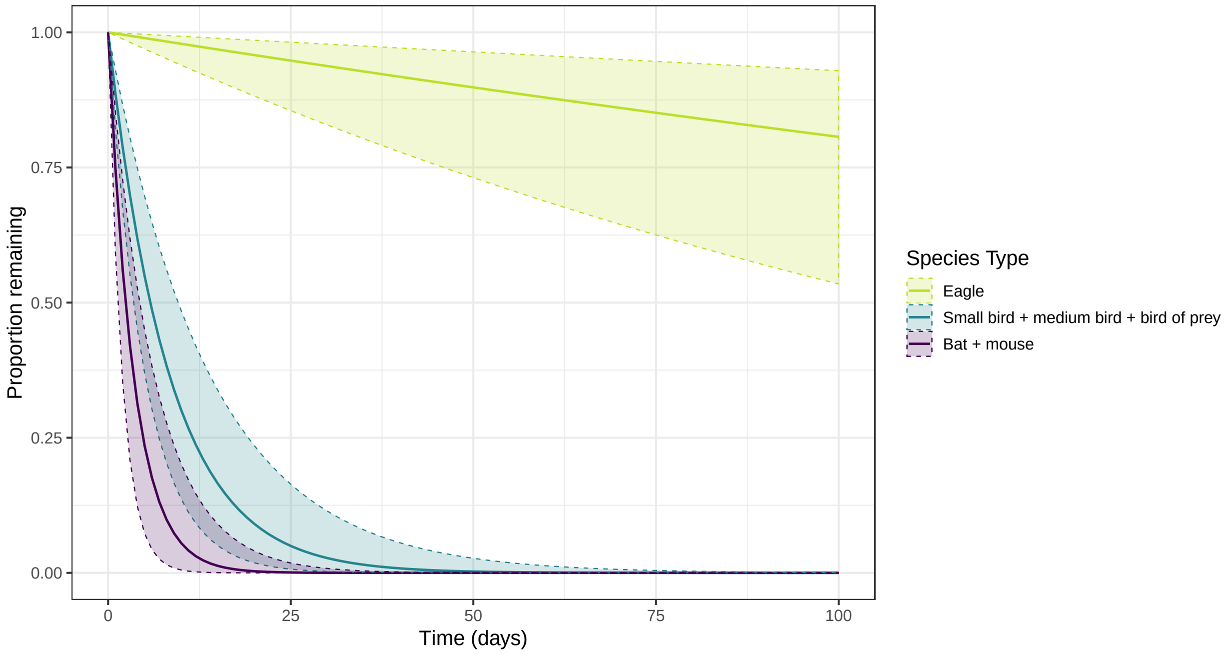

Figure 1: Comparative plot of scavenger rates of different species types (January only) with associated confidence intervals (shaded region).

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 South 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 South, for medium sized birds and bats. Medium birds at Portland included the Ringnecked Parrot and Magpie, and medium birds at Yaloak South 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 South's, by a factor of approximately 0.48.

References

Kaplan, Edward L, and Paul Meier. 1958. "Nonparametric Estimation from Incomplete Observations." *Journal of the American Statistical Association* 53 (282). Taylor & Francis: 457–81.

Symbolix. 2019. "Yaloak South Wind Farm Mortality Estimate - Year 1." Symbolix.