Report 238

YEAR 2 Bird and Bat Mortality Monitoring Survey

Silverton Wind Farm, NSW

Year 2: February 2021 to November 2021

Prepared by

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SUMMARY

Introduction

Elmoby Ecology was commissioned by data collection specialists Skylos Ecology Pty Ltd to summarise post-construction bird and bat monitoring results at the Silverton Wind Farm for GE Renewable Energy Australia Pty Ltd.

Data presented was collected by Skylos Ecology's detection dog teams and analysed by Symbolix Pty Ltd.

This report summarises the two year monitoring program with additional details of the final ten months of the post-construction mortality monitoring program, from February 2021 to November 2021. This report should be considered as an update to the first year report. This report addresses the reporting requirements from Table 8 in Section 4 of the approved Bird and Bat Adaptive Management Plan (BBAMP, Biosis 2018).

Methods

The methods for the three components of this report were undertaken in accordance with the approved BBAMP, and are provided in greater detail in Section 2 below. The three components are:

- Searcher efficiency / detectability (Section 2.2)
- Carcass persistence / scavenger loss rates (Section 2.3)
- Carcass searchers / mortality estimates (Section 2.4)

Data Analysis

Statistical analyses for the 10-month monitoring data was undertaken by Symbolix Pty Ltd. Mortality estimations were obtained using Monte-Carlo simulations.

Results

No species of concern were found and no impact triggers were reached during the 10-month survey period of this report.

Searcher efficiency / detectability

Three searcher efficiency trials were conducted (two in November 2020, and one in May 2021). Trials used both bird (n = 49) and bat (n = 63) carcasses. Detectability (i.e., the likelihood of finding a carcass) did not differ between birds and bats, nor between different dog-handler teams; therefore, a single detectability estimate for all carcasses of 99% (95% confidence interval (CI) [95%,100%]) was applied.

Carcass persistence / scavenger loss rates

Two carcass persistence trials were conducted each year in Autumn and Spring (May 2020, November 2020, May 2021, and August 2021). Trials used bats (*n* = 5), bat proxies (mice; *n* = 35), and birds of various sizes (*n* = 40). Cameras took photos of carcasses every hour to determine the period of time that carcasses were removed.

The scavenging rate did not differ between birds and bats; therefore, the data were aggregated. The median time to total loss of a carcass via scavenging for birds and bats at Silverton Wind Farm is 1.1 days (95% CI [0.8,1.8] days).

Carcass searches / mortality estimates

In the 10-month survey period from February 2021 to November 2021, 2 bat carcasses (one inland freetail bat and one Gould's wattled bat) and 1 bird carcass (a wedge-tailed eagle) were recorded during the 304 formal surveys conducted. All three species are listed as common and secure in their range.

An additional 7 bats and 6 birds were found outside of the formal survey areas or times (i.e., incidental finds): 1 inland forest bat, 1 white-striped freetail bat, 3 inland freetail bats, 1 Gould's wattled bat, 2 wedge-tailed eagles, 1 little button quail, 1 masked wood swallow, 1 nankeen kestrel, and 1 bird and 1 bat that were unable to be identified. All identified species found are listed as common and secure in their range.

Discussion

The estimated average of bats impacted during the survey period was 103, with 95% confidence that less than 220 bats were impacted.

It was not possible to estimate the number of birds impacted in the second year due to the low number of finds and reduced survey effort relative to Year 1 (Year 1: 14 months, Year 2: 10 months).

Rainfall totals during both Year 1 and Year 2 were lower than average, and several years of lower-than-average rainfall were recorded prior to the commencement of this study. It is thus possible that reduced activity on site due to dry climatic conditions explains the lower finds; however, it is also possible that current survey protocols are not adequate to detect a mortality event. Given the number of incidental finds (i.e., carcasses found outside of formal survey areas and/or times) were higher than formal finds in both Year 1 and Year 2, the current survey design was evaluated for its efficacy.

No species of concern were found and no impact triggers were reached during the 10-month survey period of this Year 2 report; therefore, no significant impacts are recorded.

Survey Design Review

Survey design parameters were reviewed following the year 1 report in order to determine if current survey protocols are adequate to detect a mortality event, should one occur, given the low number of carcasses found.

Increasing the number of surveys from 348 to 696 per year and including all turbines on site would more than double opportunities for carcass detection and significantly increase the confidence in the derived mortality estimates.

Recommendations

- Monitoring the site with an increased survey effort during a wet year would provide greater understanding of fluctuating collision risks.
- Increasing survey effort to ensure finds during routine surveys are higher than those found incidentally would also provide greater confidence of the survey design.

Document Information

Report Name	YEAR 2 Bird and Bat Mortality Monitoring Survey Silverton Wind Farm, NSW
Report to	Skylos Ecology Pty Ltd GE Renewable Energy Australia Pty Ltd
Prepared by	Emma Bennett of Elmoby Ecology Dr Stevie Nicole Florent of Skylos Ecology
Data analysis by	Symbolix Pty Ltd
This study was undertaken on site at the Silverton Wind Farm with consent from the Land manager	GE Renewable Energy Australia Pty Ltd
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Contents

1 INTRODUCTION

1.1 Background

This report summarises the second-year post-construction bird and bat mortality detection findings at Silverton Wind Farm in accordance with Section 4 of the approved Bird and Bat Adaptive Management Plan (BBAMP, Biosis 2018).

The BBAMP was finalised by Biosis Pty Ltd in May 2018, and carcass detection surveys commenced in November 2019. Prior to this, *ad hoc* surveys were undertaken post-commissioning.

The Year 1 Report (Elmoby Ecology 2020) refers to searchers conducted from November 2019 to December 2020 (14 months). Surveys were not conducted in January 2021 due to Covid-19 restrictions on site access. This report refers to surveys conducted from February 2021 to November 2021 (10 months), and thus completes the 24-month monitoring requirements of the BBAMP.

This report particularly addresses the measures identified in Table 8 under Section 4.2 of the BBAMP 2018, which pertains to results analysis and reporting of mortality searchers and estimation of total mortality of all species detected across the wind farm (Table 1).

1.1.1 Permits

Specimen collection and use were conducted under Section 2.8 (1)(a) of the Biodiversity Conservation Act 2016, which provides a defence for activities undertaken as part of a planning approval, provided that they are required for the development and are in accordance with a development consent or other approval.

As the possession of the animals is required by the development approval associated with the wind farm, the NSW Department of Planning, Industry, and Environment's advice was that an additional defence in the form of a biodiversity conservation (scientific) licence was not required.

Licences are only required for 'harm' and 'dealing in' protected animals. The use of a detection dog to locate carcasses and associated training is unlikely to result in any such offence, provided the development related survey is undertaken as the primary purpose.

1.2 Scope and Objective

As outlined in the BBAMP, the primary scope of mortality detection surveys is to meet the requirements of Condition 19 of Schedule 3 of the MOD 3 (d), which requires:

> *"…a detailed program to monitor and report on the effectiveness of these* [Condition 19, schedule 3] *measures, and any bird or bat strikes on site."*

Identifying the type and number of species impacted through the monitoring program enables estimation of total annual collisions across the wind farm site to be calculated with associated confidence intervals.

Table 1. Requirements for the Analysis of Results. Adapted from* Bird & bat adaptive management plan for Silverton Wind Farm*, Section 4.2, Table 8, pg. 23 (Biosis 2018).

Action	Timing / frequency	Measure	Responsible party	Status
Determine collision results relative to trigger levels.	Following each search cycle	Results exceeded trigger levels have been reported to OEH* within 48 hours. Other results have been reported within 10 business days	Skylos Ecology Pty Ltd.	Completed second year
Calculate mean rates of searcher efficiency and carcass persistence, relevant for all species of interest	Within 3 months of the completion of monitoring, including trials for the year, in year of the monitoring program	Results have been reported to OEH within 10 business days	Symbolix Pty Ltd	Completed second year
Use mean scavenge and searcher efficiency rates in combination with the results of mortality searches to estimate total mortality of all species of interest detected in carcass searches at the wind farm, along with associated 95% confidence intervals.	Within 3 months of the completion of monitoring, including trials for the year, in year of the monitoring program	Results exceeded trigger levels have been reported to OEH within 48 hours. Other results have been reported within 10 business days	Symbolix Pty Ltd and Elmoby Ecology Pty Ltd	This report

* OEH: Office of Environment and Heritage.

1.3 Study Area

Silverton Wind Farm is located in the Barrier Ranges of New South Wales (Fig. 1). Its south-western boundary is approximately five kilometres (km) north of Silverton and 24 km northwest of Broken Hill. The wind farm consists of 58 turbines situated in a steep and rocky landscape with significant drops and highly dissected rock ground. As such, the survey area is restricted to hardstands and roads within a 70-metre distance from a turbine.

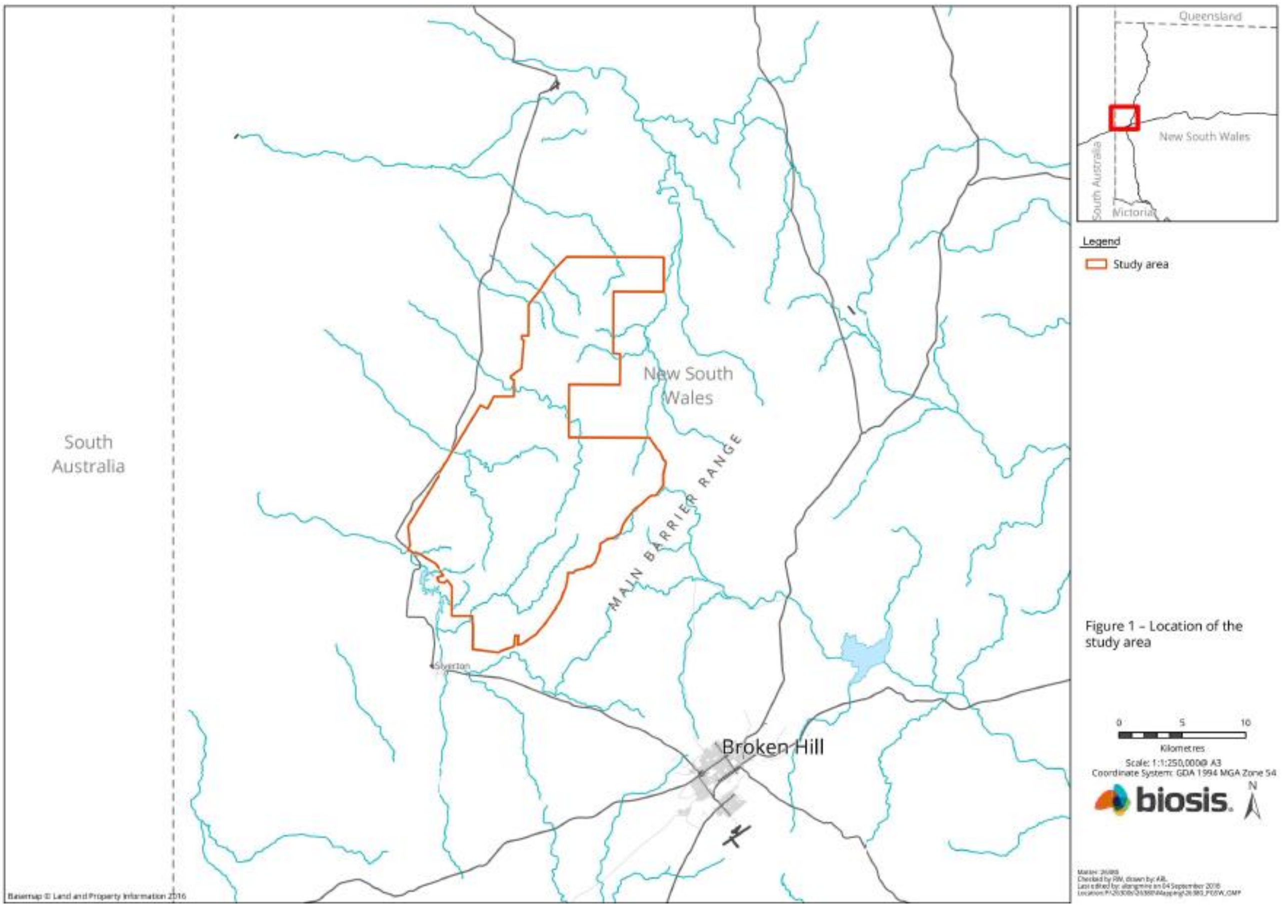

Figure 1. Location of Silverton Wind Farm. Image obtained from Biosis.

1.4 Use of detection dogs

Skylos Ecology detection dog teams conducted surveys at Silverton Wind Farm. The use of detection dog teams is considerably more effective and efficient than human surveyors (Matthews *et al.* 2013; Smallwood *et al.* 2020). Detection dogs are trained to use their olfactory abilities to locate bird and bat carcasses. Dogs work free from the lead and along transects to search the entire survey area, and indicate to their handlers upon finding a carcass.

1.5 Survey types

There are two survey types mentioned in this report (see Section 4.1.4 of BBAMP, Biosis 2018):

- Standard: Monthly survey to 70 m radius around the turbine, roads and hardstands only.
- Pulse: Replication survey conducted two days later to 70 m radius around the turbine to account for scavenger activity. Please note that Pulse surveys were reduced from three days to two days following advice from NSW DPIE (Andrew Fisher, Senior Team Leader, Planning – South West, Biodiversity and Conservation, NSW DPIE, 02-Dec-20).

2 METHODS

2.1 Data Analysis Overview

Different bird and bat mortality monitoring requirements and survey designs apply across New South Wales wind farms, meaning that data analyses must account for differences in survey effort, survey detection success, and scavenger efficiency.

Data analyses for this report were undertaken by Symbolix Pty Ltd using Monte-Carlo simulations. These simulations account for these aforementioned differences.

2.2 Searcher Efficiency / Detectability

Searcher efficiency or detectability trials were conducted twice in Year 1 and once in Year 2. Only one trial was conducted in Year 2 due to Covid-19-related site access issues (see Appendix 4). These trials determine the likelihood of a survey team detecting a carcass if one is present. At Silverton Wind Farm, detectability is higher due to the reduced survey area of hardstands and roads; thus, high detectability is likely for any survey method in this instance.

A range of bats (*n* = 63) and small to medium birds (*n* = 49) were used in the detection trials. White-striped freetail bats and eastern falsistrelles were typically used for bats, and peregrine falcons, nankeen kestrels, and currawongs for birds. It is not necessary to test for the detection of large carcasses such as eagles, as they have a detectability of 100% on hard stands and roads (i.e., all are always found). Dog-handler teams and human-only searchers were used; however, all Year 2 surveys were conducted by dog-handler teams only, thus Year 2 detectability was estimated using dog-handler teams only.

To conduct searcher efficiency trials, carcasses were randomly distributed throughout the survey area at least one hour prior to search team arrival. To ensure dogs are not tracking the scent of the human placing the carcasses, carcasses were thrown from a randomly designated point and allowed to land naturally. GPS coordinates of the throw location and direction are recorded, and an indirect path was taken back to the vehicle. Whilst handlers are aware of the trial being conducted, they are unaware of the bait status of any particular turbine, that is, what turbines are a part of the trial, how many carcasses are at any particular turbine, or what carcass types (i.e., bird, bat, bat proxy) are at any particular turbine. This ensures sufficient blinding to validate the testing.

To ensure no additional effort was made during efficiency trials by handlers, survey duration was recoded for comparison to standard surveys.

2.2.1 Data Analysis

Data were provided to Symbolix to allow for correction based on observational bias, that is, to ensure survey duration did not differ between trials and normal formal surveys. The data were also tested via AIC selection to determine if there was any difference in detectability for bird and bat carcasses.

2.3 Carcass Persistence Trials / Scavenger Loss Rates

Quantifying the removal rate of carcasses by scavengers is essential for understanding how many carcasses are available for detection by observers and to provide correction factors for subsequent impact estimates, i.e., it allows us to see how accurate our modelling is. The primary method of carcass removal is likely to be scavenging by dingos, foxes, raptors, magpies, and crows.

Two carcass persistence trials were undertaken each year (Year 1 and Year 2) in Autumn (May 2020 and May 2021) and Spring (November 2020 and August 2021). Trials used a mixture of bats, bat proxies (mice), and various sized birds, with a collective total of 80 carcasses (Table 2). Mice were used as a proxy for bat carcasses due to the low number of bat carcasses available for the trial. They are the most suitable proxy for estimating bat carcass persistence, although they may lead to a slightly shorter estimate of time to scavenge (Symbolix 2020).

Carcasses were monitored by fixed cameras for 30 days, with photos taken hourly to determine the period of time that a carcass was removed. Cameras were manually checked on days 1, 3, and 12. All carcasses were placed within the 70 m survey area of the turbines along roads or hardstands, with the exception of a wedge-tailed eagle which was placed over 200 m from the turbine base to reduce the risk of scavenging eagles colliding with the turbines.

Table 2. Carcass type and number placed per carcass persistence trial. Mice were used as a proxy for bat carcasses due to the low number of bat carcasses available for the trials.

Species type	Trial 1 (May 2020)	Trial 2 (November 2020)	Trial 3 (May 2021)	Trial 4 (August 2021)
Bat	4	1	0	0
Mouse	6	9	10	10
Bird	10	10	10	10

2.3.1 Data Analysis

Survival analysis (Kaplan and Meier 1958) was used to determine the average time a carcass remained in the field before scavenging. This analysis was required as the exact time of scavenging was unknown, only the interval of time in which the scavenging event occurred. By fitting a curve to the data, we can estimate the average proportion of bird and bat carcasses remaining after a given length of time, despite the unknowns.

2.4 Carcass Searches / Mortality Estimates

Mortality surveys were conducted monthly by Skylos Ecology's trained detection dogs and handlers from February 2021 until November 2021. Twenty-nine turbines were randomly selected from the 58 onsite. Surveys were conducted on a two-month roster, with 14 turbines surveyed the first month, and the remaining 15 surveyed the second month (Table 3).

A particular turbine's survey month would consist of a 'standard' survey, with a 'pulse' survey conducted two days later. This was done to increase the likelihood of detection of small bats and birds, and to reduce the impact of scavengers on mortality estimates following results from carcass persistence trials. Due to logistical planning, monthly surveys took place at the beginning or end of each calendar month, maintaining a four- to five-week gap between survey trips. This led to some survey dates overlapping into the previous or following month; however, the number of scheduled surveys was equal to the number of surveys conducted (Table 3).

Dogs used olfactory detection of carcasses and are free to roam the site, generally commencing downwind and working across the wind to survey the area. Due to the constrained size of sites, dogs made two passes along each road travelling up and back from the turbine to 70 m and searching the hard stand from downwind and across the site. Despite the reduced survey area, dogs located carcasses off roads and hardstands; however, these are considered incidental finds and are not included in the final analysis.

2.4.1 Data Analysis

Mortality estimations are calculated via two separate Monte-Carlo simulations, one for bats and one for birds. Each uses 25,000 simulations of the survey design. Random numbers of virtual mortalities are constructed, along with the scavenge loss time and searcher efficiency (based on measured confidence intervals) and corrected factors for the reduced surveyed area are applied. The estimations are provided for the period of 01-01-2021 to 04-11-2021, to allow for mortality to occur up to one month prior to the first survey.

The proportion of virtual carcasses "found" is recorded for each simulation. Finally, those simulations that had the same outcome as the reported survey detections are collated, and the initial conditions (i.e., how many true losses) are reported on.

The 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, including the model assumptions, can be found in Appendix 2.

Table 3. Number of mortality surveys scheduled and conducted per month at Silverton Wind Farm from February to November 2021. Roster month 1 involved surveying a group of 14 turbines, whilst roster month 2 involved surveying a group of 15 turbines. Due to logistical planning, surveys took place at the beginning or end of each calendar month, meaning some survey dates overlapped into the previous or following month, hence the difference between the number of surveys scheduled and the number conducted in any given month.

Month	Roster month (1 or 2)	Number of surveys scheduled	Number of surveys conducted
February	1	44	44
March	2	28	58
April	1	30	0
May	2	28	28
June	1	30	44
July	2	28	14
August	1	30	44
September	2	28	14
October	1	30	30
November	2	28	28
Total		304	304

3 RESULTS

3.1 Searcher Efficiency / Detectability

Three trials were held at Silverton Wind Farm over the two-year study period using both bird (*n* = 63) and bat (*n* = 49) carcasses. Large carcasses such as eagles were assumed to have 100% detectability on roads and hardstands, and were therefore not assessed in these trials. There was no evidence that searcher efficiency / detectability differed between birds and bats, and thus a single detection value is provided.

In summary, across the three trials, dog-handler teams had a detectability of 99% (95% CI [95, 100], Table 4). This data is consistent with other data on detection dogs searching roads and hardstands collected over the past 5 years.

Table 4. Detectability of bird and bat carcasses for dog-handler teams at Silverton Wind Farm from three searcher efficiency / detectability trials conducted over 2020 and 2021. Note: trials were conducted on roads and hardstands only to replicate formal survey scenarios.

Variable	Value
Number of carcasses found	102
Number of carcasses placed	103
Mean detectability (proportion)	0.99
Detectability lower bound (95% confidence interval)	0.95
Detectability upper bound (95% confidence interval)	1

3.2 Carcass Persistence Trials / Scavenger Loss Rates

Two carcass persistence trials were conducted in Year 2 in Autumn (May) and Spring (August), with 80 carcasses placed (bats; *n* = 5, bat proxies (mice); *n* = 35, birds; *n* = 40). Thirteen carcasses were taken on the day of placement, 12 the following day, 11 more by day 4, and only one mouse carcass remained at the completion of the trial (day 31).

There was no evidence from the analysis that birds and bats/bat proxies have any meaningfully different scavenger rate, and thus the data were combined. Additionally, there was no measurable difference between Year 1 and Year 2 trials, and therefore all data was combined to provide a more confident estimate.

The survival curve (solid line) fitted to the scavenger data show the estimated proportion of carcasses remaining at any given time, with shaded portions providing the 95% confidence intervals on the estimates (Figure 2). For example, we can be 95% confidence that between 8% and 25% of carcasses will persist to 10 days, with a mean expectation that 14% will remain.

In summary, the mean time to total loss via scavenge is 1.1 days, with a 95% CI of [0.8, 1.8] days.

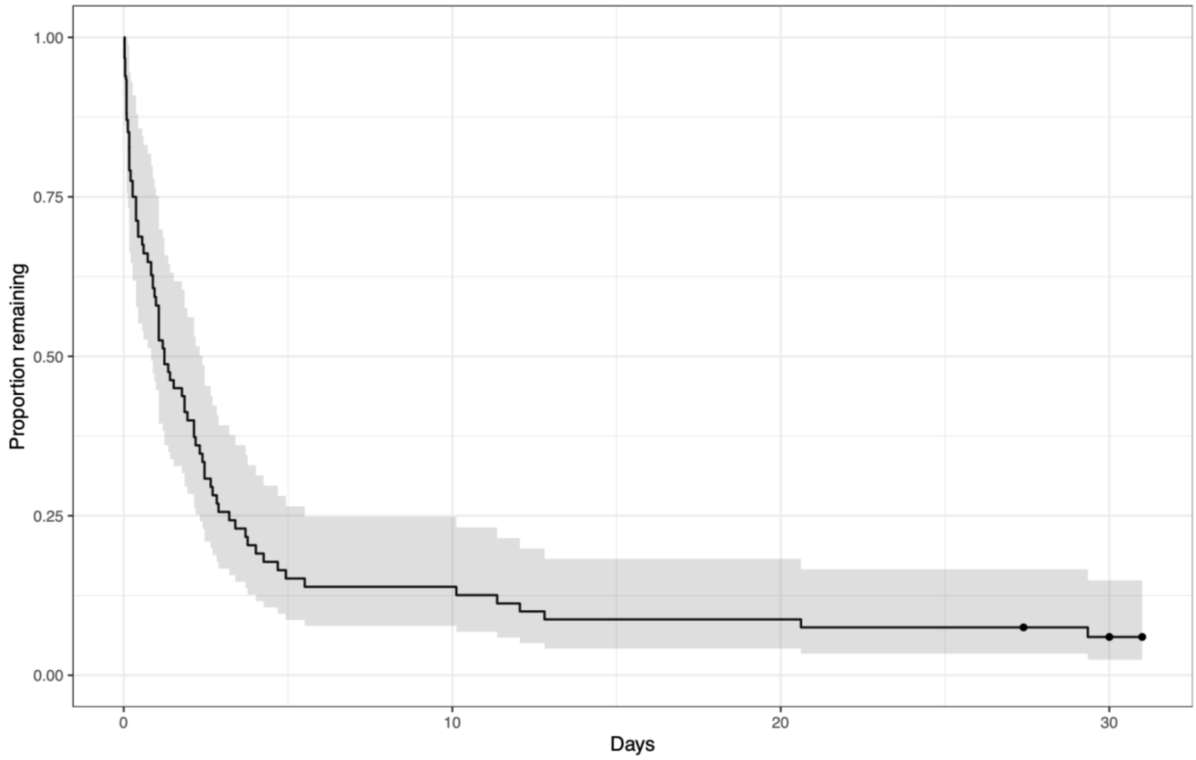

Figure 2. Survival curve for birds and bats, showing the estimated proportion of carcasses at the Silverton Wind Farm remaining at any given time. The solid line provides a mean estimate, while the shaded portions provide the 95% confidence interval. This data is based on four carcass persistence trials over two years (Year 1, 2020 and Year 2, 2021).

3.3 Carcass Searches / Mortality Estimates

Two bats and 1 bird were found during formal mortality searches (Table 5) with an additional 6 birds and 7 bats found incidentally (i.e., outside of formal survey area and/or times; Table 6). Twelve of the 13 incidental finds were found within 70 m. Two of the three wedge-tailed eagle carcasses found (one during formal surveys and one incidentally) were found at Turbine 35.

No threatened species were found during formal surveys or as incidental finds.

Table 5. Carcasses found during formal surveys at Silverton Wind Farm in Year 2 post-construction, including their distance from turbine, the turbine number, the month found, and whether they were complete carcasses or there was evidence of scavenger activity.

Species	Distance from turbine (metres)	Turbine	Month, Year	Condition (complete or scavenged)
Inland freetail bat	61 m	27	Feb, 2021	Complete
Gould's wattled bat	30 m	36	Feb, 2021	Complete
Wedge-tailed eagle	7 m	35	Feb, 2021	Scavenged

Table 6. Incidental carcass finds located outside of formal survey areas and/or times.

	Species	Turbine	Distance from turbine (metres)	Date
Bats	Inland forest bat	25	27 m	05-Oct-21
	Gould's wattled bat	58	36 m	01-Mar-21
	White-striped free-tailed bat	1	35 m	04-Nov-20
	Inland freetail bat	N/A	N/A	12-Jan-21
	Inland freetail bat	32	34 m	04-Feb-21
	Inland freetail bat	36	67 m	29-Mar-21
	Unidentified bat	35	17 m	01-Feb-21
Birds	Nankeen kestrel	45	12 m	01-Mar-21
	Masked wood swallow	21	50 m	09-Dec-20
	Little button quail	29	33 m	06-Nov-20
	Wedge-tailed eagle	30	48 m	04-Nov-20
	Wedge-tailed eagle	35	52 m	01-Jun-21
	Unidentified bird	2	1 m	06-Dec-20

3.3.1 Mortality estimation for bats

During formal surveys in Year 2, two bats were found on the roads and hardstands. The resulting estimate, which accounts for searcher efficiency, carcass persistence, and search area, is an expected mean loss of 103 bats for the 10-month period, and a median of 90 bats lost (Figure 3).

Based on the detected carcasses, there is 95% confidence that fewer than 220 individuals were lost across the site (Table 7).

This equates to an average number of 1.8 bats likely to have been impacted per turbine over the survey period, with 95% confidence that less than 3.8 bats per turbine were impacted

Table 7. Percentiles (confidence) of estimated total bat losses over the second year of surveys.

Confidence percentile	0%	50% (median)	90%	95%	99%	99.9%
Total bat losses	4	90	184	220	321	392

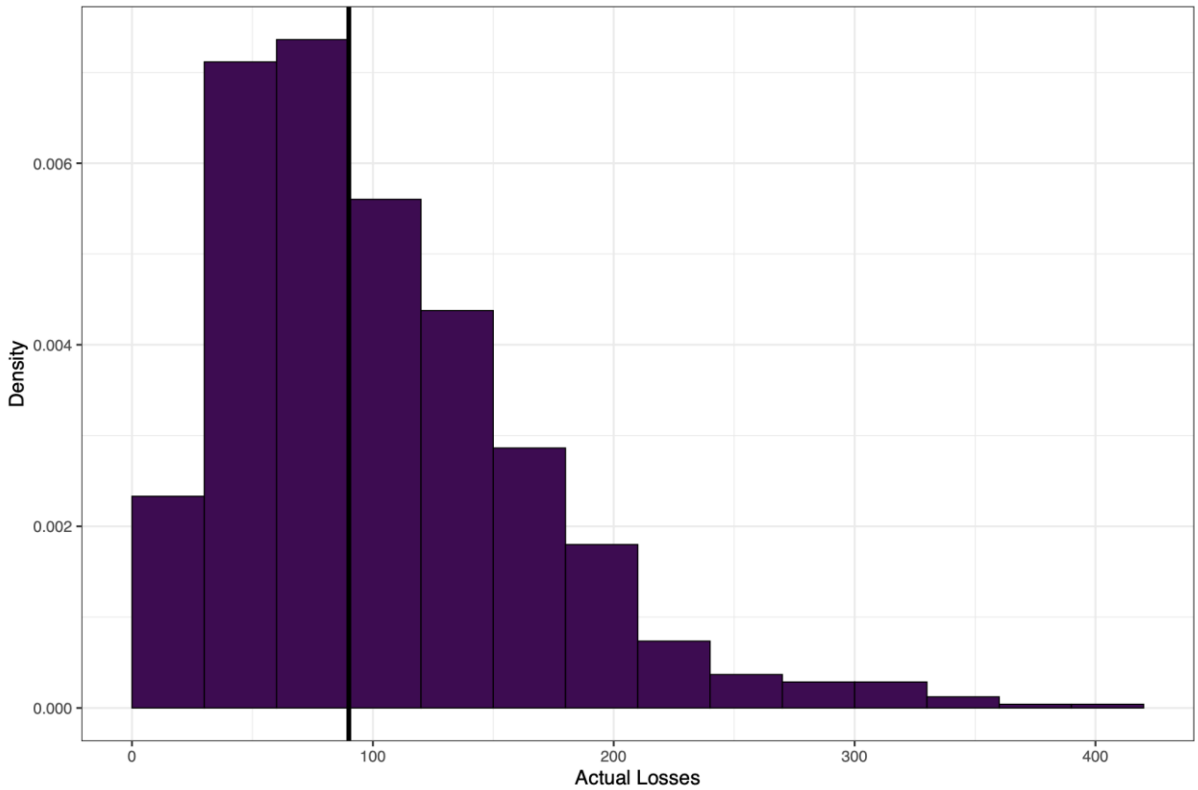

Figure 3. Histogram depicting the distribution of total losses for bats at Silverton Wind Farm, given two were detected on site. The solid black line shows the median.

3.3.2 Mortality estimation for birds

During formal surveys in Year 2, one bird was found. Due to the reduced number of surveys compared to Year 1 (928 in Year 1 compared to 304 in Year 2, Elmoby Ecology 2020) and single carcass find, there is insufficient information to calculate a mortality estimate for birds.

4 DISCUSSION

4.1 Searcher Efficiency / Detectability

Detectability of both birds and bats by dog-handler teams is 99%, with a 95% CI of [95%, 100%]. This is consistent with other wind farm sites utilising dog-handler teams and searching roads and hardstands only.

There was no difference in detectability of birds and bats by the dog-handler teams, and this is primarily driven by the dog's use of olfactory rather than visual detection. Dogs are particularly advantageous over humans for detecting small targets such as bats and small birds (Mathews et al. 2013, Smallwood 2020), and thus the use of dogs at Silverton Wind Farm provides the most robust survey method for maximising detection success.

4.2 Carcass Persistence Trials / Scavenger Loss Rates

The median time of a carcass being totally lost via scavenging at Silverton Wind Farm is 1.1 days, 95% CI [0.8,1.8] days.

This is low when compared to other wind farm sites. For example, the site-wide mean persistence for carcasses at Victoria wind farms is 2.7 days (95% CI [2.1, 3.4]) for bats, 5.7 days (95% CI [4.8, 6.8]) for birds, and over 280 days for wedge-tail eagles (Symbolix 2020). There is currently no similar data available for NSW or for sites similar to Silverton Wind Farm.

The ability to detect carcasses on roads and hardstands is high for both human and dog survey teams, and thus it may also be higher for scavenging animals. Additionally, limited food resources during the sustained period of drought in the area around Silverton Wind Farm may make scavenging more desirable, thus reducing carcass persistence.

The reduction of the interval between standard and pulse surveys from three days to two days has reduced the uncertainty of low persistence on bird and bat mortality estimates.

4.3 Carcass Searches / Mortality Estimates

Based on the detected carcasses, there is 95% confidence that less than 220 individuals were impacted during the Year 2 monitoring period. The expected mean loss of bats at Silverton Wind Farm for the 10-month survey period of Year 2 is 103 bats, with a median (50% confidence) of 90 bats. This equates to an average number of 1.8 bats likely to have been impacted per turbine over the survey period, with 95% confidence that less than 3.8 bats per turbine were impacted.

These values are much higher than the 14-month survey period of Year 1, which estimated less than 75 bats were impacted (95% confidence), with an expected mean loss of 33 bats (Elmoby Ecology 2021). Even with these higher values, it is also important to note that the Year 2 monitoring period does not include the seasonally active bat period of November to January.

Although Year 2 findings were higher than Year 1, the overall low number of formal bat carcass finds means that estimates are based on a limited data set. This adds uncertainty to the estimations. Similarly, there was an inability to provide mortality estimates for birds at Silverton Wind Farm as only a single carcass was found, and although the average number of birds likely to be impacted per turbine per year is probably low, there is no certainty around this estimate.

There are two non-exclusive hypotheses for these low figures: 1) they could be a true indication of a low impact to bats and birds; or 2) the current survey protocols are not adequate for finding carcasses.

1) A true low impact:

The expected number of bats impacted per turbine at Silverton Wind Farm is low when compared to most other wind farms in Australia and overseas, where bat impacts often exceed 8 to 9 bats per turbine per year (Symbolix 2020). Population densities for bats are likely lower at Silverton Wind Farm than other sites in Australia which may account for lower bat mortalities, although a correlation between bat activity and mortality has not been undertaken in Australia and therefore conclusions about population densities and impacts cannot be drawn.

Bird activity has decreased since pre-construction, most likely due to dry climatic conditions. It is possible that during both survey periods (Year 1 and Year 2) dry conditions have reduced activity and therefore actual finds are low. With this in mind, increasing rain activity is likely to lead to greater bird and bat activity, which may lead to a higher collision risk for this site. It is particularly worth noting that more than half of the annual rainfall was recorded during November 2021, just after the formal survey period concluded.

Comparing estimates from the Silverton Wind Farm to wind farms elsewhere in Victoria or NSW is unlikely to offer any meaningful insights due to the different climatic zone and resident bird and bat species; however, understanding how changing climatic conditions influences collision risk for birds is necessary to develop robust estimates of the impact of Silverton Wind Farm on bird and bat populations.

2) Inadequate survey protocols:

The initial survey effort in the first six months of Year 1 was high and provided a good opportunity to detect carcasses if they were there to be found. This survey period also correlated with decreased activity on site due to the extended period of drought and unfortuneatly is not representative of the life of the wind farm. Subsequent reduced survey efforts restricted opportunities for carcass detection, and, as climate conditions changed, favouring increased bird activity in the region, survey effort declined, meaning that estimates for bird impacts were not able to be presented for Year 2 surveys.

The number of incidental finds in both Year 1 and Year 2 outnumbered formal survey finds. Year 1 saw 12 incidental finds and 2 formal finds, whilst Year 2 has seen 13 incidental finds and 3 formal finds, with the incidental bird finds in particularly being six times higher than those found during formal surveys. As such, Symbolix were asked to review the survey design to determine if current protocols were adequate to detect a mortality event, should one occur. The findings of this are outlined below in Section 5, pg. 23.

4.4 Significant Impacts

Events considered or defined as a significant impact are outlined in Section 3.1 and 3.2 of the endorsed Bird and Bat Adaptive Management Plan for Silverton Wind Farm (Biosis 2018). No species of concern were found and no impact triggers were reached during the 10-month survey period of this Year 2 report, thus no significant impacts are recorded.

5. SURVEY DESIGN REVIEW

5.1 Rationale

When such a low number of carcasses are detected during surveys, it is necessary to ask two questions:

1. Is this indicative of very low mortality impacts?
2. Is the survey design adequate to detect mortality events if they occur?

As such, given the low number of bird and bat carcasses detected during formal surveys, Symbolix were asked to review the survey design parameters to determine if the current survey protocols are able to detect a mortality event, should one occur. This review was conducted using Year 1 survey data (Elmoby Ecology 2021, Appendix 5).

Whilst activity of birds during the survey period was low (Biosis), it was estimated that, on average, 18 birds were impacted across the site during Year 1, with a maximum of 56 birds impacted; however, the survey effort did not detect any of these incidents during routine surveys. In order to understand if impacts were very low, we thus investigated the likelihood of detecting a carcass under differing survey conditions.

5.2 Methods

Three survey options (Option 2, 3, and 4) were compared against the current survey method (Option 1) to determine if small changes in the survey design could increase opportunities for carcass detections (Table 8). Comparisons were made using Monte-Carlo simulations, which generate simulated mortalities and compare the probability of detection under different search scenarios. Full methods to compare survey protocols can be found in Appendix 3.

5.3 Results

5.3.1 Probability of Detection

For all scenarios where actual bird and bat mortalities are low (less than 50), there is a large degree of variation in the proportion of finds, which is to be expected when mortality events are rare.

When actual mortality events are above 50, the proportion of carcass detections becomes consistent, although there is still a large scatter in the proportion found (see Figure 2, Appendix 2).

Table 8 compares the best-fit probabilities for each survey design. Option 4 has the highest probability of detecting carcasses, followed by Option 3, Option 2, and then Option 1 (the current survey design). Options 2, 3, and 4 are at least twice as successful in detecting a carcass than the current survey design.

Table 8. Alternative survey designs (Options 2, 3, and 4) in comparison with the current survey design (Option 1) and the percentage of bird and bat carcasses found for each survey option when mortalities exceed 50 per year. For rare species and low mortalities, there is a lot more variation in the probability of detection.

Survey option	Option 1 (current)	Option 2	Option 3	Option 4
Design	14 turbines one month with pulse survey 2 days later + 15 turbines the next month with pulse survey 2 days later	29 surveys per month + pulse survey 2 days later (All 58 turbines searched over a two-month period)	All 58 turbines searched once per month (no pulse surveys)	All 58 turbines survey once per month + pulse survey 2 days later at 15 turbines
Number of surveys per year	348	696	696	876
Proportion of bats found	4.9%	9.7%	10.6%	12.0%
Proportion of birds found	3.0%	6.2%	6.6%	7.5%

5.3.2 Probability of Finding Evidence

For the different survey options, we also explored the probability of finding at least one carcass if a small number of individuals were struck, i.e., for a given number of mortality events (turbine strikes), what is the chance that at least one carcass will be found?

This uses the same simulated data as above, but analysed in a slightly different way (see Appendix 3 for full details).

Figure 4 shows the probability of finding a carcass (y axis) given varying numbers of mortalities (x axis). The different options are highlighted different colours, with Option 1 the dark purple line. The top graph shows the probabilities for birds, whilst the bottom graph shows the probabilities for bats. There is little practical difference between Options 2, 3, and 4, but they are all much better at finding any evidence of mortality compared to Option 1.

For low numbers of mortalities (i.e., less than 5 bats or less than 10 birds), all survey designs have a less than 50% chance of finding a carcass. As the number of mortalities increases, the probability of finding a carcass increases. When 50 mortalities is reached, the probability of finding a carcass is close to 100% for Options 2, 3, and 4. For the same probability to be reached for Option 1, it would take close to 100 mortalities.

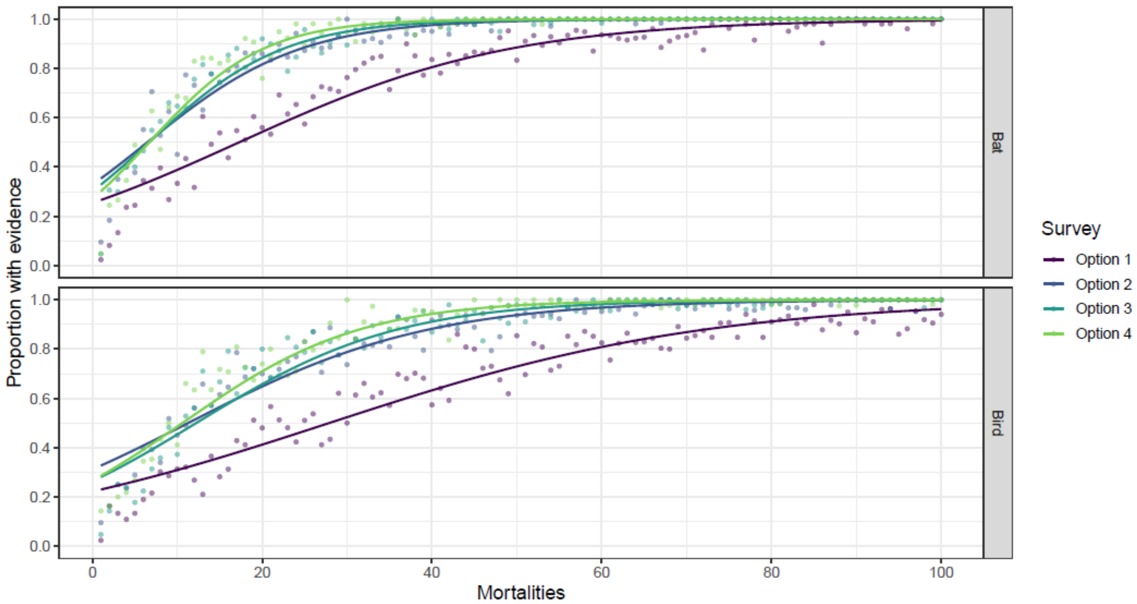

Figure 4. Probability of finding evidence given different numbers of mortalities under the different survey designs.

5.4 Implications

Implementing Options 2, 3, or 4 for the survey design, rather than Option 1, would at least double the probability of detecting a carcass and thus increase the certainty around bird and bat mortality estimates at Silverton Wind Farm.

Whilst Option 4 has the highest probability of detection, any of the alternative designs are markedly better than the current survey design of Option 1.

At present, there is only a 3% probability of detection for bird carcasses at Silverton Wind Farm; thus, a single bird detection during formal surveys over 24 months is not unexpected. Moving to Options 3 or 4 more than doubles the chance of detection for both birds and bats and will provide more certainty that a single carcass count is actually representative of the impact, and not a product of survey effort.

6. RECOMMENDATIONS

6.1 Searcher Efficiency / Detectability

Searcher efficiency trials demonstrated high detection by dog-handler teams for both birds and bats (99% detectability with 95% CI [95%,100%]). If further trials are conducted using the same teams, then it is justified to reduce detectability trials to one per year.

6.2 Carcass Persistence Trials / Scavenger Loss Rates

Carcass persistence trials undertaken at Silverton Wind Farm are representative of the dryer than average climate under which they were conducted. If further carcass searches are conducted during average or wet climates, then it is recommended that further carcass persistence trials occur simultaneously to calibrate persistence and scavenger activity relative to the survey period.

6.3 Carcass Searches / Mortality Estimates

Reported mortalities for both birds and bats at Silverton Wind Farm are low relative to reported impacts elsewhere in Australia (Symbolix 2020).

This may be due to the persistent dry conditions at the site, contributing to low site usage by birds and bats during the survey periods, leading to the lower collision rates recorded; however, it may be that during years of higher rainfall this may not hold true.

The low probability of detection of the current survey design (4.9% for bats and 3.0% for birds), means that even common bird and common bat carcass detections are rare events and the chance of finding a rare or threatened species, if they are impacted, is significantly lower.

Undertaking additional surveys, as recommended in Section 5, particularly during a wet year, will increase detection probability and provide a clearer picture of the overall impact of the wind farm to local birds and bats allowing for a more meaningful evaluation of the impact of the wind farm. Tailoring the survey program to increase chances of successful detection of impacted species may mean surveying more regularly during periods of high bird or bat activity, and reducing surveys when activity is low (such as dry season/wet season or summer/winter).

If surveying is to continue, it is worth reviewing the survey distance of 70m from the base of the turbine in line with current literature on the fall zones of carcasses.

7. REFERENCES

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8. APPENDIX

1. Section 4 BBAMP summary table of completed actions
2. Symbolix Report: Silverton Wind Farm Mortality Estimate Year 1
3. Symbolix Report: Assessment of survey designs at Silverton Wind Farm
4. Detectability Trial Results for human and dog-handler teams at Silverton Wind Farm
5. Elmoby Ecology 2021. YEAR 1 Bird and Bat Mortality Monitoring Survey, Silverton Wind Farm, NSW. Report for GE Renewable Energy Pty Ltd. Bennett, E. Elmoby Ecology, Clunes Vic. Project No. 233

Appendix 1 – Section 4 BBAMP Summary table of completed actions

Approved BBAMP (Biosis 2018) for Silverton Wind Farm. Section 4, Table 4, pg. 16.

Action	Measure	Responsible Party	Status
Engage dog handler or human observer team(s) with experience at undertaking carcass searches at wind farms.	Demonstrate consideration of both dog handler or human observer search options	Dog teams engaged by GE renewables	completed
Train dog-handler / human observer teams on how to undertake the carcass searches and collect the requisite information	Record the date of induction	Skylos Ecology (previous experience)	completed
Undertake turbine collision carcass searches at 29 turbines (15 turbines in one month, 14 turbines in the next month) using a dog-handler team or human observers	Documented number of carcasses detected for each species. Documented search frequency and effort.	Skylos Ecology undertook and documented search effort	completed
Collection, recording, storage & carcass disposal	Using turbine mortality data sheet	Skylos Ecology	completed
Review carcass search regime	Submission of report to OEH	Skylos Ecology in conjunction with advice from Biosis, Elmoby Ecology and Symbolix	completed
A freezer will be available for the purpose of storing bird and bat carcasses	Correspondence with Australia Museum	Skylos Ecology	completed
Apply for a permit under the *Biodiversity Conservation Act 2016* to collect and store bird and bat carcasses	Timely permit application to OEH under the *Biodiversity Conversation Act 2016*	Unnecessary due to section Biodiversity Conversation Act section 2.8 Acts authorised under other legislation etc, 1(a)	completed
Identify and collect all dead bird and bat carcasses upon discovery and complete data sheets for each carcass collected	Completed turbine mortality data sheets for all collected bird and bat carcasses, logged in the annual report	Skylos Ecology	Completed / ongoing

ELMOBY ECOLOGY

Action	Measure	Responsible Party	Status
Appropriately label and store bird and bat carcasses	Documented notification correspondence to OEH and the Australian Museum	Skylos Ecology	Completed / ongoing
Implement scavenger trials	Completed carcass persistence trial data sheets, calculation of average persistence times	Skylos Ecology and Symbolix	Completed / ongoing
Undertake searcher efficiency trials	Trial dates and findings are recorded and reported in the annual report, and used to assist in the review of the monitoring program	Elmoby Ecology	Completed / ongoing
Training of site personnel on procedures for bird and bat carcasses found incidentally	Inductions have been completed for all site personnel and date of attendance has been recorded.	GE Renewables	Completed / ongoing
Photography of incidentally encountered bird and bat carcasses; completion of relevant data form	Completed dead or injured bird/bat data sheet, also recorded in the annual report	Skylos Ecology and Elmoby Ecology	Completed / ongoing

Appendix 2 - Symbolix Report: Silverton Wind Farm Year 2 mortality estimate

Silverton Wind Farm Mortality Estimate - Year 2

Prepared for Elmoby Ecology, 9 December 2021, Ver. 1.1

This report outlines an analysis of the mortality data collected at the Silverton Wind Farm from 2021-02-01 to 2021-11-04. The analysis is broken into the three related components below:

- Searcher efficiency / detectability – estimated from trials in May 2020, November 2020 and May 2021
- Scavenger loss rates – consisting of trials in May 2020, November 2020, May 2021 and August 2021
- Mortality estimates - based on monthly surveys at 29 turbines, from 2021-02-01 to 2021-11-04

A mortality estimate is provided only for bats, as only one bird has been found during formal searches over two years.

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

Available data

The data analysed was collected, verified and provided to us from Skylos Ecology.

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 (Manuela MP 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

Three searcher efficiency trials were held (2020-05-11, 2020-11-05 and 2021-05-06). A range of carcass sizes and species types were used. White-striped Freetail Bats and Eastern Falsistrelles were mainly used as the bat archetype, while bird carcasses included Peregrine Falcons, Nankeen Kestrels, and Currawongs. Canine and human searchers were used. However, because all surveys in year two used dogs we have estimated detectability using canine searchers only.

The detectability trials used both bird (49 replicates) and bat carcasses (63 replicates). We found no evidence that searcher efficiency differed between birds and bats via AICc selection, and thus have aggregated them in the mortality estimate. Similarly, we found no evidence that searcher efficiency differed between the surveys held on 2020-05-11, 2020-11-05 and 2021-05-06.

Table 1 summarises the result.

Detectability using canine searchers is 99%, with a 95% confidence interval of [95%, 100%].

Table 1: Detection efficiencies for canine observers.

Variable	Dog
Number found	102
Number placed	103
Mean detectability proportion	0.99
Detectability lower bound (95% confidence interval)	0.95
Detectability upper bound (95% confidence interval)	1

Scavenger efficiency

Scavenger efficiency trials were conducted in May 2020, November 2020, May 2021 and August 2021. They used a mixture of bats (five replicates), bat proxies (mice; 35 replicates), and birds of various sizes (40 replicates). Cameras were used, which took photos every hour.

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 no evidence (via AIC scores) that birds and bats/bat proxies have significantly different scavenger rates. Therefore, in the following mortality estimate, bird and bat scavenger rates are aggregated.

Figure 1 shows a survival curve fitted to the combined cohort of bats and birds. 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 8% to 25% of bat and bird carcasses to remain after ten days with the expectation being around 14%.

Under these assumptions, the median time to total loss via scavenge for bats and birds is 1.1 days, with a 95% confidence window of [0.8, 1.8] days.

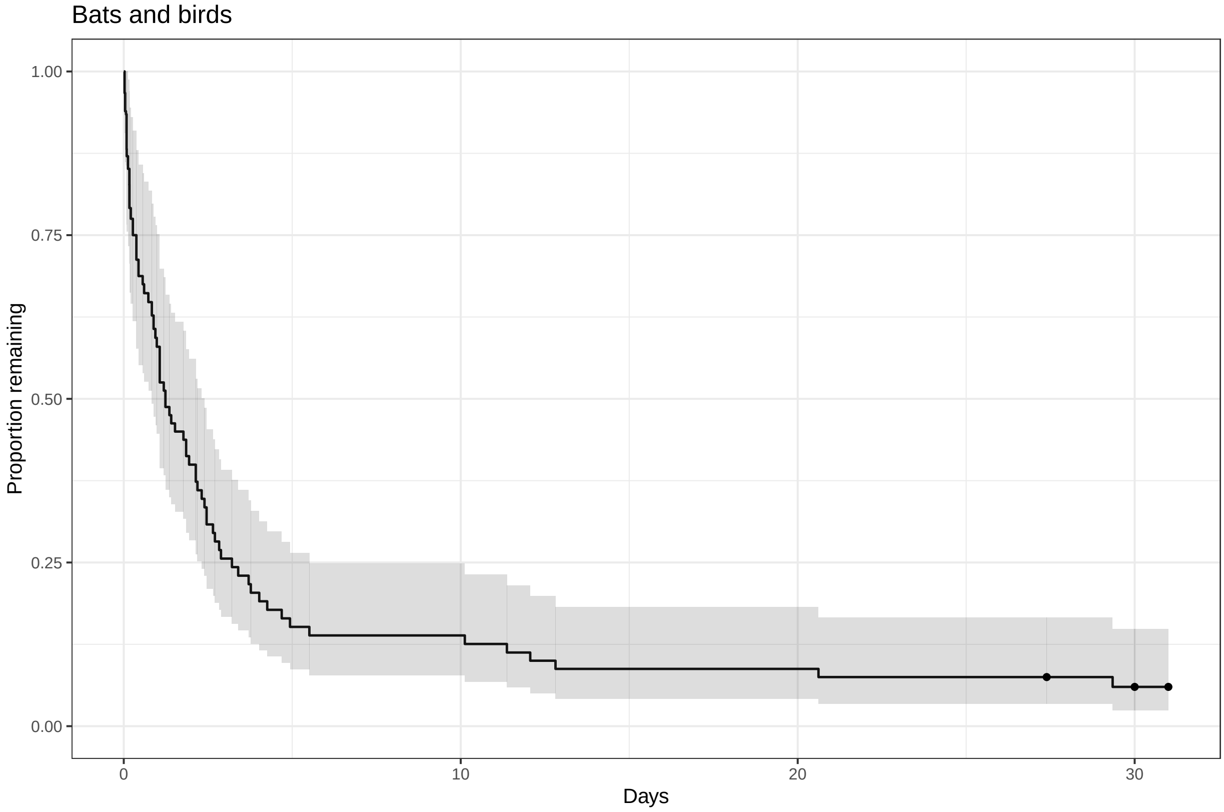

Figure 1: Combined survival curves for birds and bats, with 95% confidence interval shaded.

Mortality projection inputs

Carcass search data

The mortality estimate was based on a dated list of turbine surveys. The survey frequency is summarised in Table 2. 29 turbines were randomly selected, and approximately every two months a standard survey was performed followed by a pulse survey two to three days later. Searches occurred in the hardstand and road areas around the turbines out to 70 metres. Canine searchers were used for all surveys.

Table 2: Number of surveys per month.

Date	Number of surveys
2021 Feb	44
2021 Mar	58
2021 May	28
2021 Jun	44
2021 Jul	14
2021 Aug	44
2021 Sep	14
2021 Oct	30
2021 Nov	28

Mortality estimate - year two

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 Silverton Wind farm from 2021-01-01 to 2021-11-04 (we allow for collisions to occur up to a month prior to the first survey).

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 58 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 (2021-02-01) and until 2021-10-31. Turbines were not operating between 2021-11-01 and the final surveyed date (2021-11-04), so mortalities were not allowed to occur 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 a log-normal scavenge shape.
- We took scavenge loss and search efficiency rates as outlined above.
- 29 turbines surveyed and were searched out to a 70 metre radius in their hardstand / road zone only. We estimated the "coverage factor" for the survey – i.e. the total fall zone surveyed for birds and bats (using estimates of fall zone from Hull and Muir (2010), and coverage factor calculations from Manuela M. Huso, Dalthorp, and Korner-Nievergelt (2017)). In calculating the average coverage factor for each species, we also took into account the proportion of hardstand / road search area actually searched. Taking this into account, the average detectability was 39% for bats and 21% for birds.

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. We note that only one bird has been found in formal searches during the two years of surveys and thus we have not provided an estimate of bird mortalities.

Table 3: Carcasses found during formal surveys over the second year of surveys.

Species	Bat	Bird
Gould's Wattled	1	0
Inland Freetail	1	0
Wedge-tailed Eagle	0	1

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

Table 4: Incidental finds.

Species	Date
Little Button Quail	2020-11-06
White-striped free-tailed	2020-11-04
Wedge-tailed Eagle	2020-11-04
Unidentified Bird	2020-12-06
Masked Woodswallow	2020-12-09
Inland Forest Bat	2021-01-12
Unidentified Bat	2021-02-01
Inland Freetail	2021-02-04
Nankeen Kestrel	2021-03-01
Gould's Wattled	2021-03-01
Inland Freetail	2021-03-29
Wedge-tailed Eagle	2021-06-01
Inland Freetail	2021-10-05

Bat mortality estimate – results

During the second year of surveys a total of 2 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 103 and a median of 90 bats lost on site over the nine months.

Table 5 and Figure 2 displays 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 ex-

pect that there was a total site loss of around 103 bats over the survey period, and are 95% confident that fewer than 220 individuals were lost.

Table 5: Percentiles of estimated total bat losses over the second year of surveys.

0%	50% (median)	90%	95%	99%	99.9%
4	90	184	220	321	392

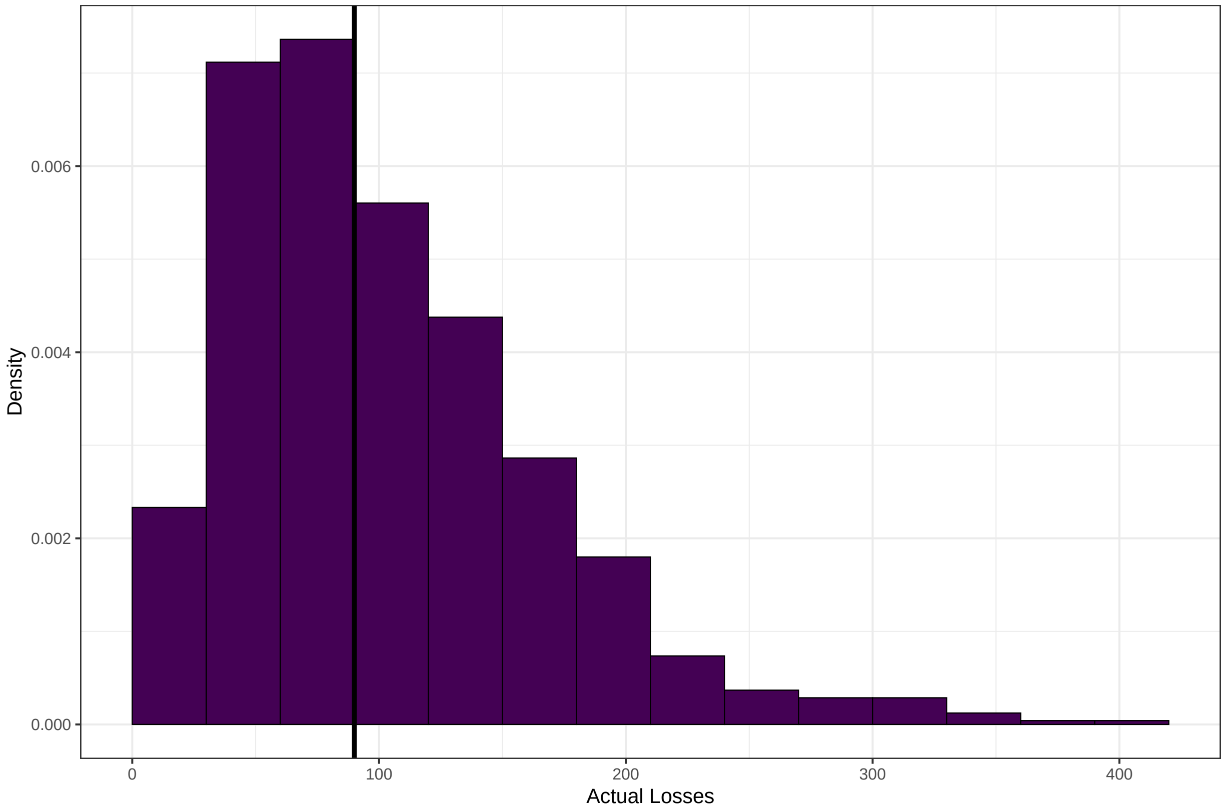

Figure 2: Histogram of the total losses distribution (bats), given 2 were detected on-site. The black solid line shows the median.

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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Appendix 3 - Symbolix Report: Assessment of survey designs at Silverton Wind Farm

symbolix

making your data work harder

To: Tracy Lyten
Skylos Ecology
Via email

Ref #: ELMSILV20210216
Date: 16 February 2021
CC: Emma Bennett

Re: Assessment of survey designs at Silverton Wind Farm

Dear Tracy,

This letter provides statistical advice on the bird and bat carcass monitoring program at Silverton Wind Farm, in western New South Wales. While the existing program is sufficient for mortality estimates, we understand the end-client would like to explore options to increase the overall probability of detecting carcasses.

We analyse four survey design options (the current program, and three alternatives) for:

a) the overall probability of detecting a carcass; and
b) the probability that some evidence of collision is found.

Survey designs

The four survey designs (also referred to as Options) are summarised below. All surveys only involve searches on the hardstand and road surrounding the turbine base, out to a maximum radius of 70 metres.

Silverton Wind Farm contains 58 total turbines.

Option 1

Option 1 is the current survey design. It involves searching 14 turbines one month, and 15 turbines the next month, with a pulse search at each searched turbine 2 days later. This comes to a total of 348 searches per year.

We have assumed that Option 1 will continue in the same fashion as in May last year, which is the **same** 14 and 15 turbines being searched in alternating months.

Option 2

Option 2 has 29 turbines searched per month, with a pulse search 2 days later. This comes to a total of 696 searches per year.

We have assumed that the 29 turbines alternate between months, i.e. the first 29 are searched in January, then the second 29 are searched in February, then the first 29 are searched in March, and so on.

Option 3

Option 3 has all 58 turbines searched once per month. This option has no pulse. This comes to a total of 696 searches per year.

Option 4

Option 4 has all 58 turbines searched per month. Additionally, there is a pulse search 2 days later at 15 turbines. This comes to a total of 876 searches per year.

Methodology and assumptions

Overview

There is no 'golden rule' governing the optimal frequency of searches. For example, we are not trying to determine the difference between classes, so a power analysis is not applicable.

We can use simulation methods to estimate the proportion of carcasses that will be found given this survey design. The same method can help us understand the likelihood of a true absence by simulating the frequency of the search protocol missing all mortalities.

It's worth remembering that the mortality estimate itself does not require coverage of all turbines and dates - only that the sample is chosen in a way that does not fail the assumptions of the Horvitz-Thompson estimator.

In this exercise we are exploring the two questions:

a) What is the overall probability that we will detect a find, given a proposed design?
b) Is absence of evidence (of collision) evidence of absence?

In the latter case we explore this by reporting the percentage of simulations that 'found' at least one carcasses, for different numbers of actual mortalities. If some (small) number of collisions occur, what is the chance we will detect it? Could modifications to the survey design substantively impact this chance?

Methods

To allow for survey protocols with non-standard intervals between searches, we developed a Monte-Carlo simulation method.

The Monte-Carlo simulation generates a representative coverage of the phase space influencing the probability of detection. We simulate mortalities at the wind farm, and then report on the number of carcasses found under the search protocol. This provides us with all the information we need to answer our two questions.

For full details on the algorithm used see Stark and Muir (2020). A summary of the algorithm flow can be found in Figure 1.

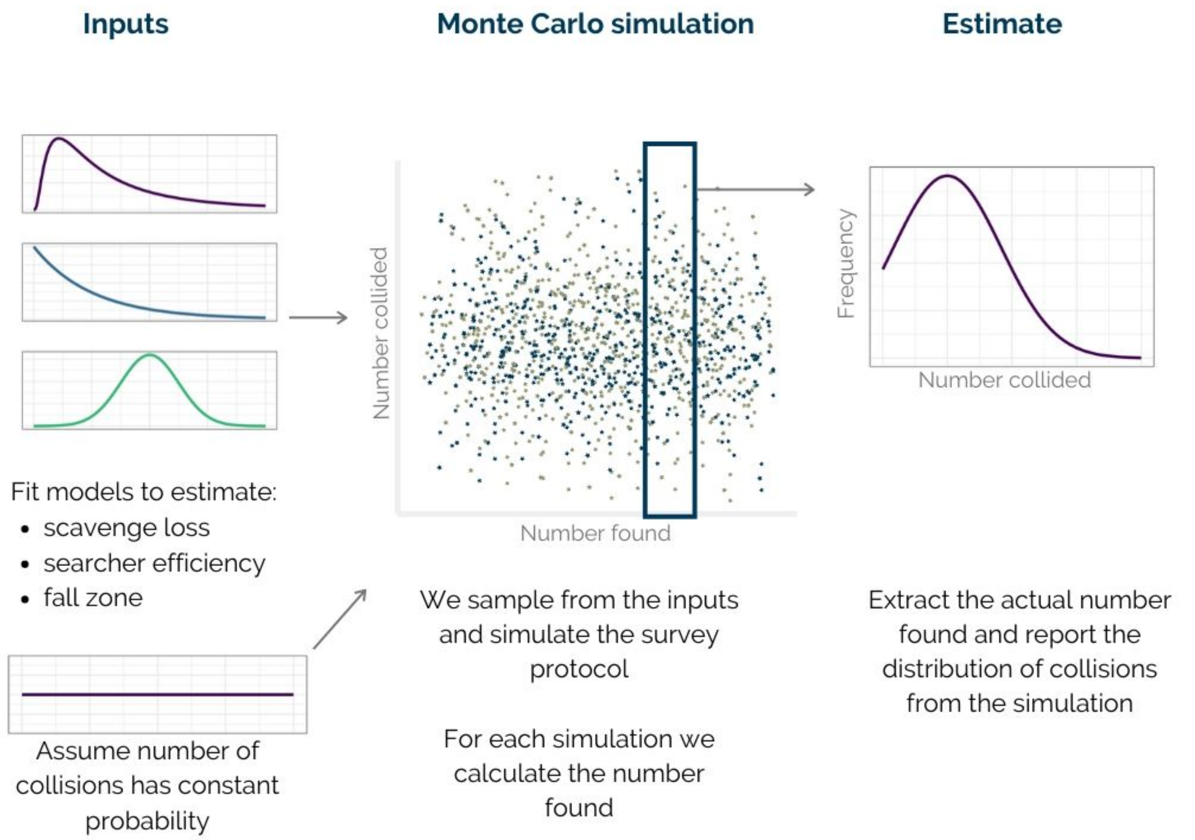

Figure 1: Schematic showing the application of the Monte-Carlo method to simulate the phase space of possible collisions and subsequent carcass finds. The inputs are based on empirical distributions estimated from field trials.

Statistical assumptions

- We used searcher efficiency and scavenger rate results from the year 1 mortality report (Symbolix 2020).
- Canine searchers only are used the simulation.
- We retain the restriction of roads and hardstand search areas. The "coverage factor" (the proportion of the fall zone of birds / bats covered by the search area) was calculated using the methods of Hull and Muir (2010) and Huso, Dalthorp, and Korner-Nievergelt (2015).

Results

Overall probability of detection

Figure 2 shows the simulation results. On the x axis we have the true number of mortalities; each black point gives the proportion of those mortalities found (for that particular simulation). The horizontal line is the "best fit" convergence probability.

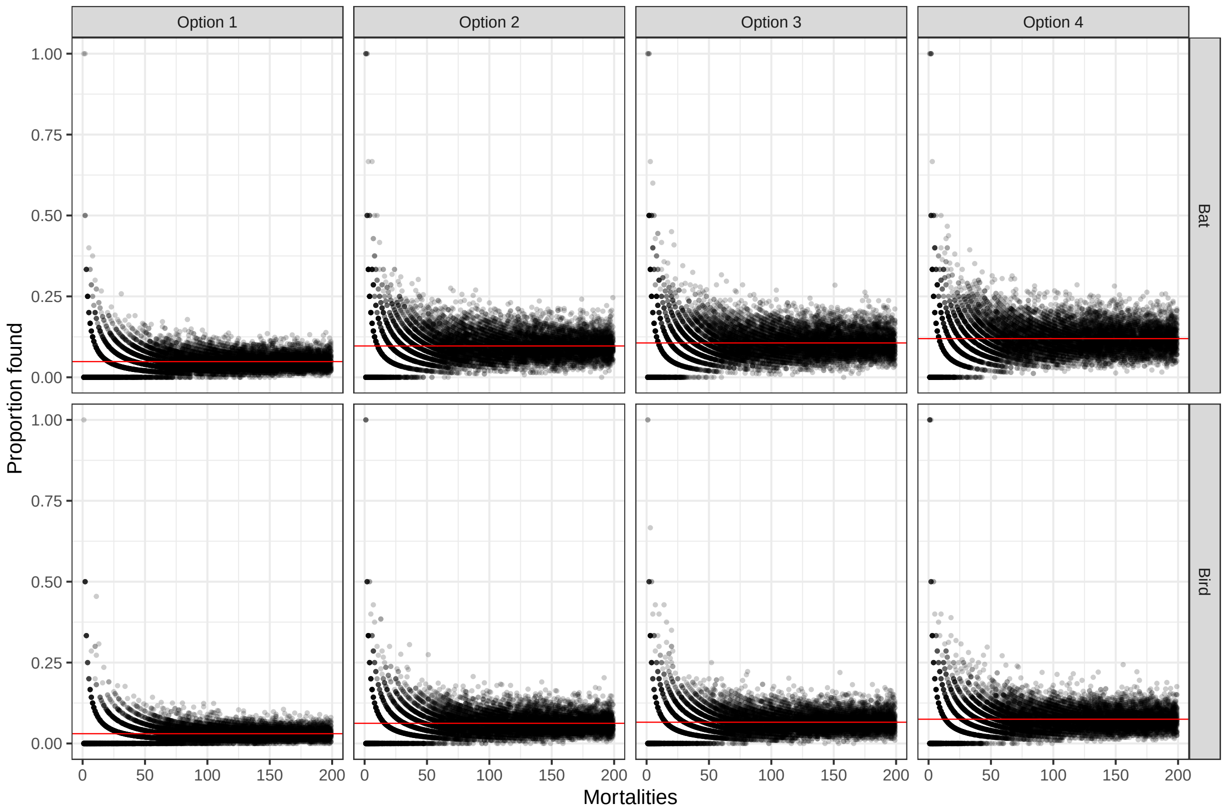

Figure 2: Probability of detecting a carcass (y axis) against the number of mortalities.

We can see that for all Options, for low numbers of mortalities (less than 50), there is a large degree of variation in the proportion of finds. Above this value, the proportion settles to a constant value. However, there is a still a large degree of variation between simulation runs (as we can see from the scatter around the red line) which is around 5 percentage points in Option 1, and 10 in the other Options.

Table 1 compares the best-fit probabilities (the horizontal red lines) for each survey design. Option 4 has the highest probability, followed by Option 3, Option 2, and finally Option 1. We can see that Options 2, 3, and 4 are of the order twice as "good" as the current Option 1 (if we take it that "good" means maximising the probability of detection).

Table 1: Percentages of bat and bird carcasses found, for each survey option.

Option	Bat (%)	Bird (%)
Option 4	12.0	7.5
Option 3	10.6	6.6
Option 2	9.7	6.2
Option 1	4.9	3.0

Note that these probabilities only apply at an overall level - for rare species with expected low mortalities, there is a lot more variation in the chance that you find the carcass.

Probability of finding evidence

In this section we look at the probability that you find evidence - i.e. if some number were struck, what is the chance that you find at least one carcass? We use the same simulated data as in the above section, but analyse it in a slightly different way.

Figure 3 shows the probability of finding evidence of mortality (y axis) given varying numbers of mortalities (x axis). The points are results from the simulation, with the lines coming from a smoothing GAM fit (to aid the eye). It's immediately evident that Options 2, 3, and 4 are more effective at finding evidence of mortality, compared to Option 1. While Option 4 appears to be fractionally superior compared to Options 2 and 3, there is little practical difference between them.

For low numbers of mortalities (less than 5 bats, or less than 10 birds), all survey designs have a less than 50% chance of finding evidence of mortality. Figure 4 zooms in on these low numbers of mortalities, for clarity of the curve. The implication of this is: the mortality estimation survey program on its own is not sufficient for providing evidence of mortality for rare species. Other streams of evidence would be required in conjunction with the program.

As the number of mortalities increases, the probability of finding evidence increases towards 100%. We can see from Figure 3 that by the time we have 50 mortalities, the chance of evidence is close to 100% for Options 2, 3, and 4, while it takes close to 100 mortalities for the same chance of evidence for Option 1.

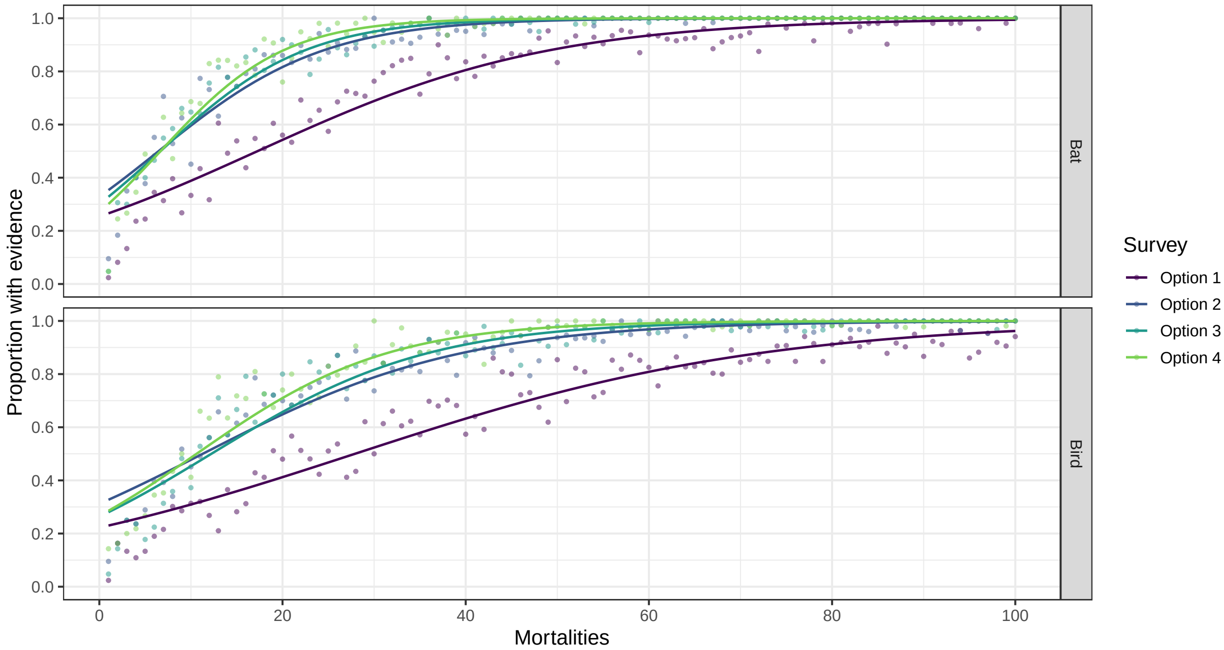

Figure 3: Probability of finding evidence given different numbers of mortalities, under the various survey designs.

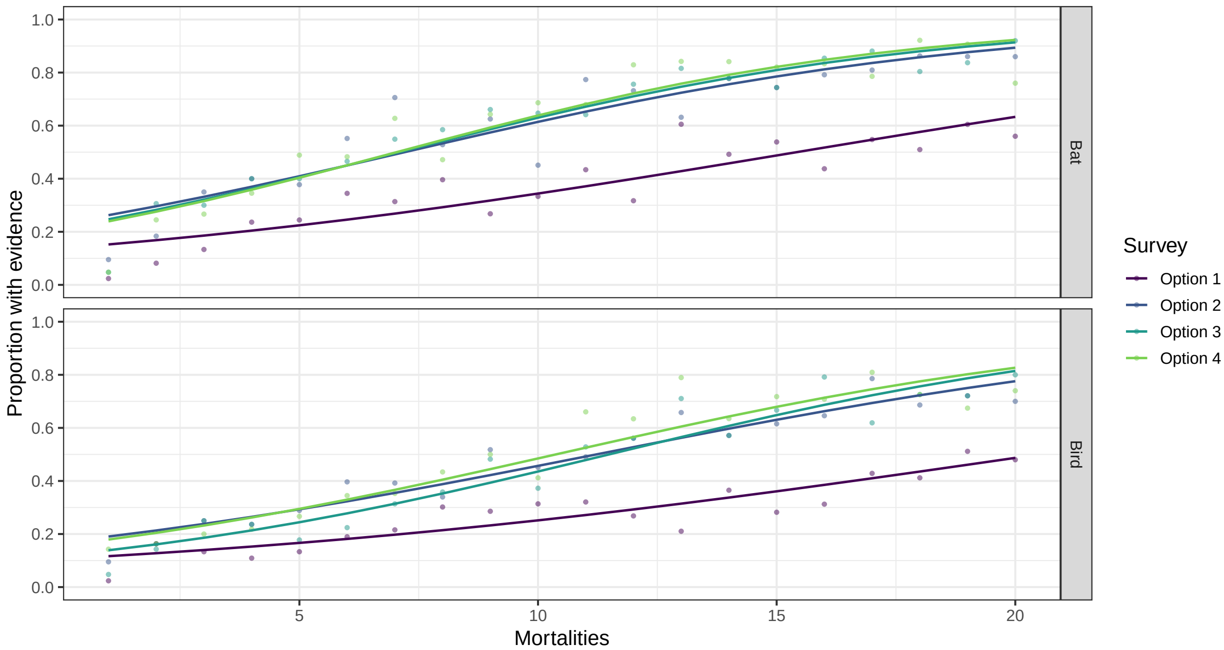

Figure 4: Zoomed-in section of Figure 3 for less than 20 mortalities, with the GAM smoother refit.

Conclusions and recommendations

In terms of overall probability of detection, Option 4 has the highest probability of detection of the competing designs, followed by 3, and then 2. This applies to both birds and bats - moving from Option 1 to any of the other options will double the overall probability of detection, at least.

In terms of probability of evidence, again Option 4 is the best design - however, there is not a lot distinguishing it from 2 and 3. Options 2, 3, and 4 are markedly superior to Option 1.

We recommend moving from the current survey design of Option 1, to one of the alternatives (Options 2, 3, or 4). If possible, Option 4 is preferred, due to its higher performance - however, the three alternatives are all significantly better than the current design, and are generally comparable. Therefore Options 2 and 3 would also be acceptable choices.

If you have any further questions or comments, please do not hesitate to contact us.

Regards,

Mr Alex Jackson

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References

Hull, C., 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 (2): 77–87.

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Stark, E, and S Muir. 2020. “Post Construction Bird and Bat Monitoring at Wind Farms in Victoria.”

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Appendix 4 - Detectability Trial Results for human and dog-handler teams at Silverton Wind Farm

A second searcher efficiency / detectability trial in Year 2 was not possible due to ongoing Covid-19-related site access issues. At the time the trial was scheduled, border closures between NSW and Victoria were in place, and the 14-day required quarantine period was not possible for Principal Ecologist Emma Bennett from Elmoby Ecology to complete upon her return to Victoria. Due to the short notice of the border restrictions, there was no other possible alternative.

Emma Bennett stated that she is ‘satisfied that there is enough detection trial data in the dog and handler team at Silverton to propose abandoning the final detection trial in light of the Covid-19 restrictions’ and does not believe ‘this will impact the quality of the data as results have been consistent and high over the previous three trials’.

Emma also conducts detectability trials on the Skylos Ecology dog teams at the Salt Creek and Dundonnell wind farms in Victoria, and she stated: ‘If further evidence is required then your results from Victorian trials reinforces the consistency of your detection rates and could be used to supplement the data during analysis.’

The results of the three previous detectability trials at Silverton Wind Farm are in Table A4.1.

Table A4.1. Detectability trial results for both human and dog-handler teams at Silverton Wind Farm. Only one trial was conducted in 2021 due to Covid-19-related site access issues.

Trial	Date	Survey type	No. Targets	No. Targets found	Confidence interval
1	May 2020	Dog team	38	38	For 91 finds from 92 samples we can say that the mean detection is 98.9% with a 95% confidence interval that the true mean is somewhere between 94.2% and 99.7%. This is presented as: **98.9% [94.2%, 99.7%].**
2	November 2020	Dog team	23	23	
3	May 2021	Dog team	31	30	
2	November 2020	Human (due to one month of access issues due to covid-19 restrictions)	9	7	For the human detection results which is 7 from 9 samples, we see 78% detection with a 95% confidence that the true mean is between 44% and 93%. This is presented as: **78% [44%, 93%].**

ELMOBY ECOLOGY

Appendix 5 - Elmoby Ecology 2021. YEAR 1 Bird and Bat Mortality Monitoring Survey, Silverton Wind Farm, NSW. Report for GE Renewable Energy Pty Ltd. Bennett, E. Elmoby Ecology, Clunes Vic. Project No. 233

ELMOBY ECOLOGY

Report 233

YEAR 1 Bird and Bat Mortality Monitoring Survey

Silverton Wind Farm, NSW

Year 1: November 2019 to December 2020

Prepared by

Emma Bennett of Elmoby Ecology

for

Skylos Ecology and GE Renewable Energy.

March 2021

ELMOBY ECOLOGY

SUMMARY

Introduction

Elmoby Ecology was commissioned by data collection specialists Skylos Ecology to summarise post construction bird and bat monitoring at the Silverton Wind Farm for GE Renewable Energy. Data was collected by Skylos Ecology's detection dog team and analysed by Symbolix Pty Ltd. This report addresses the reporting requirements from Table 8 in section 4 of the approved Bird and Bat Adaptive Management Plan (BBAMP).

The purpose of this report is to summarise the findings of the first year of the post construction mortality monitoring program (November 2019 – December 2020).

Methods

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

- Carcass Persistence (section 2.2)
- Searcher Efficiency (section 2.3)
- Carcass Searches (section 2.4)

Data Analysis

Statistical analysis for the 14-month 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

No species of concern were found and no impact triggers were reached during the 14-month survey period of this report.

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 100% with a confidence interval of [95%,100%] was applied for the dog teams (n=72) and 78% with a confidence interval of [40%, 97%] for the month of surveys conducted by human searches only.

Carcass Persistence

There was no evidence of differences between the scavenging rate of birds and bats and therefore the data was aggregated to a single estimate. Carcass persistence is 1.5 days with a 95% confidence it is between [0.8, 3] days.

Carcass Searches (14 months)

During the 14 month survey period a total of 2 finds were recorded during formal surveys, 2 bats and 0 birds. One bat was an inland freetail bat and the other a Gould's wattled bat; both species found are listed as common and secure in their range.

An additional 8 birds and 4 bats were found outside of the survey area, 1 Gould's wattled bat, 3 white striped freetail bats, 3 wedge tail eagles, 1 Australian owlet-nightjar, 1 nankeen kestrel, 1 little button quail, 1 masked wood swallow and 1 bird unable to be identified. All species found are listed as common and secure in their range.

Discussion

On average we estimate the number of bats impacted during the period of this report was 33, with a 95% confidence that fewer than 75 individuals were lost. During the same period, the average impact estimate for birds is 18, with a 95% confidence that fewer than 56 individuals were lost.

No species of concern were found and no impact triggers were reached during the 14 month survey period of this year 1 report and thus no significant impacts are recorded.

Survey Design Review

We reviewed survey design parameters in order to determine if the current survey protocols are adequate to detect a mortality event should it occur given the low number of carcasses found.   We found that increasing searches from 348 per year to 696 per year and including all turbines on site would more than double opportunities for carcass detection and significantly increase the confidence in the the derived mortality estimates.

Recommendations

Increasing survey effort from pulsed surveys at 14 turbines one month and 15 the following month to searching all turbines once per month (with or without additional pulse surveys) will significantly increase opportunities for carcass detection and provide confidence that the reported low mortality at Silverton Wind Farm is a reflection of the actual impact and not due to inadequate survey design.

ELMOBY ECOLOGY

Document Information

Report Name	YEAR 1 Bird and Bat Mortality Monitoring Survey Silverton Wind Farm, NSW
Report to	Skylos Ecology and GE Renewable Energy
Prepared by	Emma Bennett of Elmoby Ecology
Data analysis by	Symbolix Pty Ltd
This study was undertaken on site at the Silverton Wind Farm with consent from the Land manager	GE Renewable Energy
Data Collection	Fiona Jackson Tracy Lyten Dogs: Oakley, Jimmy
Citation	Elmoby Ecology 2021. YEAR 1 Bird and Bat Mortality Monitoring Survey, Silverton Wind Farm, NSW. Report for GE Renewable Energy Pty Ltd. Bennett, E. Elmoby Ecology, Clunes Vic. Project No. 233
Document Control	Draft V.01 Date Issued 2021 February Final V.01 Date Issued 2021 March Review V.03 Date Issued 2021 April

Contents

ELMOBY ECOLOGY

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 mortality detection at the Silverton Wind Farm in accordance with section 4 of the approved bird and bat Adaptive Management Plan (BBAMP).

The BBAMP was finalised by Biosis in May 2018 and searches of turbines for evidence of carcasses began in November 2019. Prior to this, adhoc searches were undertaken post commissioning until full implementation began.

For the purpose of this report, only searches conducted from November 2019 to December 2020 are included.

This report particularly addresses the measures identified in Table 8, section 4.2 of the BBAMP pertaining to the reporting of the results of the mortality searches and estimation of total mortality of all species detected across the wind farm (Table 1). A summary of the completed actions from section 4 of the BBAMP can be found

Table 1 Requirements for the Analysis of Results from Section 4.2, Table 8 of the BBMAP

BBMAP Section 4 Table	Action	Measure	Responsible Party	Status
8	Determine collision results relative to trigger levels	Results exceeded trigger levels have been reported to OEH within 48 hours. Other results have been reported within 10 business days	Skylos Ecology	Completed first year
8	Calculate mean rates of searcher efficiency and carcass persistence, relevant for all species of concern	(within 3 months of the completion of monitoring) Results have been reported to OEH within 10 business days	Symbolix	Completed first year
8	Use mean scavenge and searcher efficiency rates in combination with the results of mortality searches to estimate total mortality of all species of concern detected in carcass searches at the wind farm, along with associated 95% confidence intervals.	(within 3 months of the completion of monitoring) Results exceeded trigger levels have been reported to OEH within 48 hours. Other results have been reported within 10 business days	Symbolix and Elmoby Ecology	In review

1.1.1 Permits

Collection and use of specimens were conducted under section 2.8 (1)(a) of the Biodiversity Conservation Act 2016 (see below),which provides a defence for activities undertaken as part of a planning approval, provided that they are required for the development and in accordance with a development consent or other approval.

As the possession of the animals is required by the development approval associated with the wind farm, NSW Department of Planning, Industry and Environment's advice was that an additional defence (in the form of a biodiversity conservation (scientific) licence) is not required.

Licences are only required for 'harm' and 'dealing in' protected animals. The use of a detection dog to locate carcasses and associated training is unlikely to result in any such offences, provided the development related survey is undertaken as the primary purpose.

1.2 Scope and Objective

As outlined in the BBAMP, the primary scope of the mortality detection is to meet the requirements of Condition 19 of schedule 3 of the MOD 3 (d), which requires;

- *a detailed program to monitor and report on the effectiveness of these* [Condition 19, schedule 3] *measures, and any bird or bat strikes on site.*

Identifying the type and number of species impacted through the monitoring program enables estimates of total annual numbers of collisions across the wind farm site to be calculated with associated confidence intervals.

1.3 Study Area

Silverton Wind Farm is located in the Barrier Ranges of New South Wales (Figure 1). Its south-western boundary is approximately five kilometres north of Silverton and approximately 25 kilometres north-west of Broken Hill. The wind farm contains 58 turbines situated in a steep and rocky landscape with significant drop offs and highly dissected rocky ground. For this reason, the study area is restricted to hardstands and roads within 70m distance from the turbine.

Appendix 1

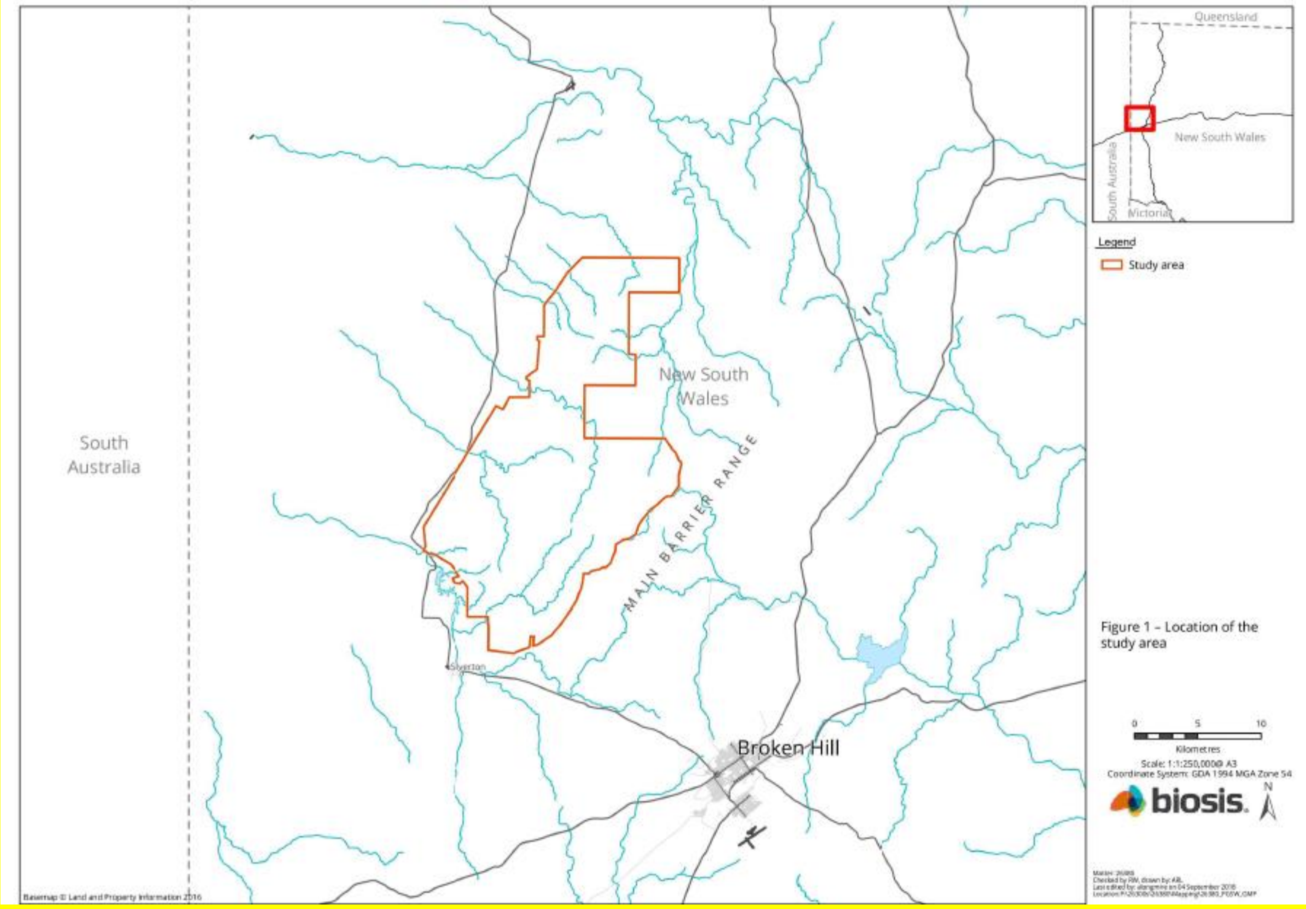

Figure 1 Location of Silverton Wind Farm.

2 METHODS

2.1 Data Analysis Overview

Different bird and bat mortality monitoring requirements apply across New South Wales wind farms meaning that data analysis must account for differences in survey effort, survey detection success and scavenger efficiency.

Data analysis for the monitoring results of this report, 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 May 2020 and November 2020 using a mixture of bats, bat proxies (mice) and various sized birds. Cameras were used to take photos hourly to determine the interval of carcass removal. The primary method of removal of carcasses is likely to be scavenging by dingos, 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.

Two carcass persistence trials were conducted in Year 1, using a collective total of 40 carcasses (Table 2). Mice were used as a proxy for bat carcasses due to the low number of bat carcasses available for the trial. Mice are the most suitable proxy for estimating bat persistence although they may lead to a slightly shorter estimation of time to scavenge (Symbolix 2020).

Table 2 Type and timing of for the deployment of carcasses during the carcass persistence trials

Species Type	May 2020	November 2020
Bat	4	1
Mouse	6	9
Bird	10	10

Monitoring of carcasses by cameras occurred for 30 days and were manually checked on days 1, 2, 3, 4 and 12. All carcasses were placed within the survey area of the turbines with the exception of an eagle which was placed greater than 200m from the turbine base to reduce the risk of collisions by scavenging eagles.

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 (refer to Appendix 2).

2.3 Searcher Efficiency

Searcher efficiency trials were conducted twice in year 1 of the study to determine the likelihood of the survey team detecting a carcass during surveys if one is present. At Silverton Wind Farm, the ease of detection is increased due to the reduced survey area of hardstands and roads only and thus high detection for any survey method is likely in this instance. A range of bats and small to medium birds were used in the detection trial, as it is not necessary to test for detection of large carcasses such as eagles as they have a detection rate on hard stands and roads of 1 (all are always found). Searcher efficiency was undertaken on the dog teams as well as the solo human surveyor who surveyed one month without dogs due to restrictions on travel imposed by the Covid-19 Pandemic.

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. Differences in detection between birds and bats is analysed using AIC selection and confidence around the estimates is presented (see Appendix 2).

2.4 Carcass Searches

Carcass surveys have been conducted by trained detection dogs and their handlers monthly from November 2019 until December 2020. For the first six months all 58 turbines were surveyed monthly, which was then reduced to 14 turbines one month and 15 turbines the next month from May 2020 through to December 2020. Additional "pulse" surveys were conducted three days later to increase the detection of small birds and bats and reduce the impact of scavengers on mortality estimates. The total number of surveys completed each month is shown in Table 3. Dogs used olfactory detection of carcasses and are free to roam the site, generally commencing downwind and working across the wind to survey the area. Due to the constrained sites, dogs made 2 passes along each road travelling up and back from the turbine to 70m and searching the hard stand from the downwind and across the site. Despite the reduced survey area, dogs also located carcasses off the roads and hardstands, however these are considered incidental finds and not included in final analysis.

Table 3 Number of surveys per month

	Month	Number of surveys
2019	November	116
	December	116
2020	January	116
	February	116
	march	116
	April	116
	May	28
	June	30
	July	28
	August	30
	September	28
	October	30
	November	28
	December	30

2.4.1 Data Analysis

The mortality estimation is done via two Monte-Carlo simulations, one for bats and one for birds. 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 the reduced area surveyed were applied. 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 2.

3 RESULTS

3.1 Searcher Efficiency

Two trials were held at Silverton using a range of carcass sizes and types (34 birds and 42 bats). An assumption was made that large carcasses such as eagles had 100% detection on the roads and hardstands and were therefore not assessed in this trial. There was no evidence that searcher efficiency differed between birds and bats and thus a single detection estimate is provided (Table 4). This data is consistent with other data on detection dogs searching roads and hardstands collected over the past 5 years.The detection rate measured for the human surveys is also consistent with other trials on human surveys, although the small sample size makes it difficult to comment on the data.

Table 4 Detection efficiency for roads and hardstands

Variable	Dog	Human
Number found	72	7
Number placed	72	9
Mean detectability proportion	1	0.78
Detectability lower bound (95% confidence interval)	0.95	0.4
Detectability upper bound (95% confidence interval)	1	0.97

3.2 Carcass persistence trials

Two carcass persistence trials were conducted in May 2020 and November 2020 with 40 carcasses placed and used for analysis. Four carcasses remained at the completion of the trials, 1 wedge tail eagle carcass in May 2020 and 2 small birds and 1 mouse carcass in the November 2020 trial. During analysis it was found that separating bats and birds did not improve model selection, and thus they were combined as an aggregate.

Survival curves fitted to the scavenge data show the estimated proportion of carcasses remaining after any given time (Figure 2). For example, we can be 95% confident that between 12% and 41% of carcass will persist to 10 days with a mean expectation that 22% will remain. In summary, the mean time to total loss via scavenge is 1.5 days with a 95% confidence window of [0.8, 3] days.

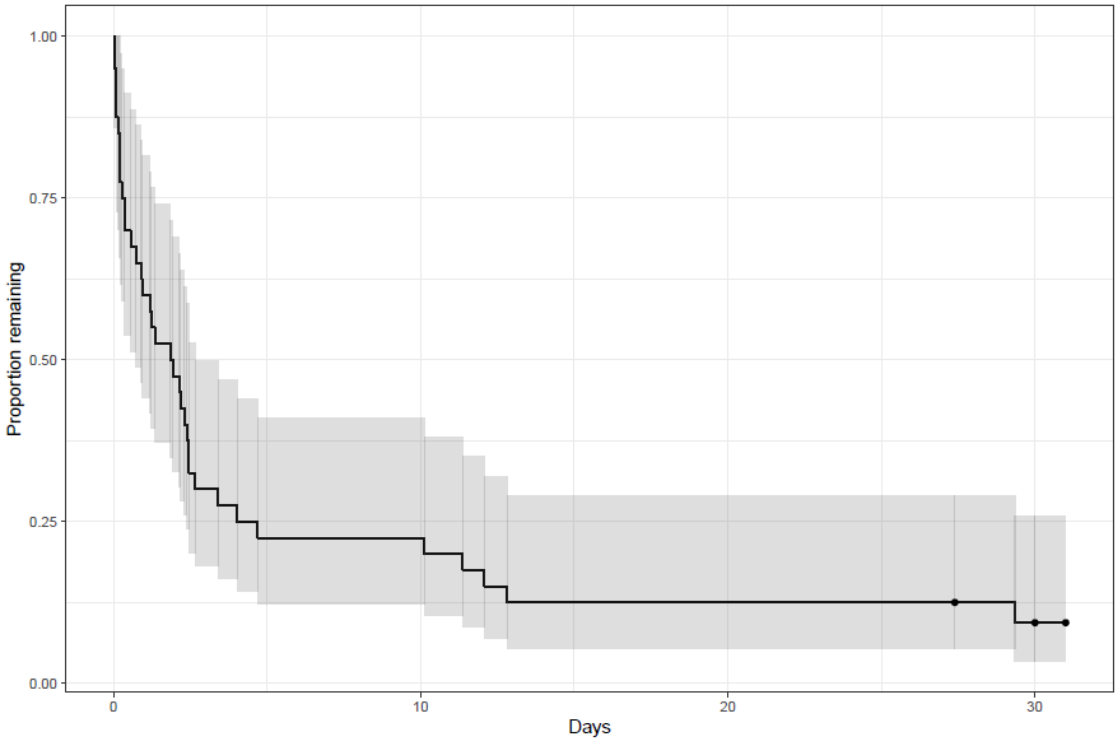

Figure 2 Survival curves with 95% confidence shaded

3.3 Carcass Searches

Carcass searches for year 1 were carried out between November 2019 and December 2020. Due to disruptions on travel in January 2021 because of the Covid-19 Pandemic, it was decided to include 14 months within the first analysis as this was representative of a dry climate with the expectation that the following year will be considered relatively wet in comparison. In total 928 turbine searches were carried at the 58 turbines with the initial 6 months encompassing all turbines, and the following 8 months a subset of 29 turbines (Table 3).

A total of 2 bats and 0 birds or feather spots were found during routine mortality searches (Table 5) with an additional 8 birds and 4 bats found outside the survey area (Table 6). No threatened species were found during surveys.

Table 5 Bat species found during routine surveys

Species	Distance from Turbine	Turbine	Month	Condition
Inland freetail bat	38m	32	Dec 2019	complete
Gould's wattled bat	12m	24	Apr 2020	complete

Table 6 Incidental finds (birds and bats) found outside routine survey area

Species	**Count**
Gould's wattled bat	1
White Striped Freetail bat	3
Australian owlet-nightjar	1
Nankeen kestrel	1
Masked wood swallow	1
Little button quail	1
Wedge tail eagle	3
Unknown bird	1

3.3.1 Mortality estimation for bats

During routine surveys in year 1 a total of 2 bats were found on the roads or hardstands. The resulting estimate accounting for searcher efficiency, carcass persistence and search area is an expected mean loss of 33 bats for the 14 month period. Based on the detected carcasses there is 95% confidence that fewer than 75 individuals were lost across the site (Figure 3).

3.3.2 Mortality estimation for birds

During the routine mortality surveys, a total of 0 birds were found at Silverton Wind Farm. The resulting estimate accounting for searcher efficiency, carcass persistence and search area is an expected mean loss of 18 birds for the 14 month period. Based on the detected carcasses there is 95% confidence that fewer than 56 individuals were lost across the site (Figure 4).

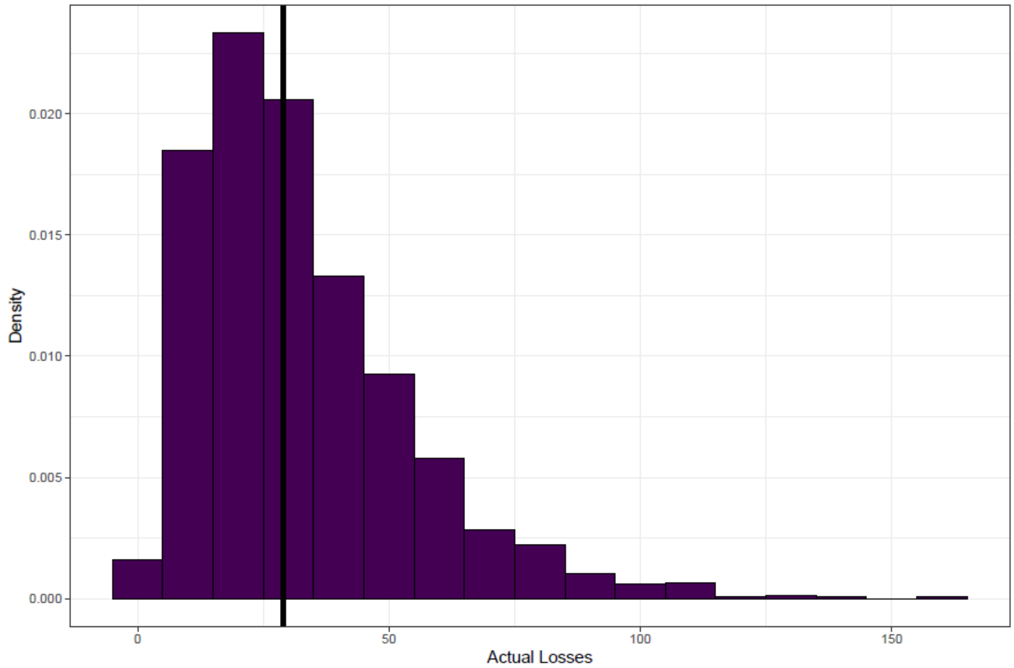

Figure 3 Histogram of the total losses distribution of bats for Silverton Wind Farm. The solid black line indicates the median.

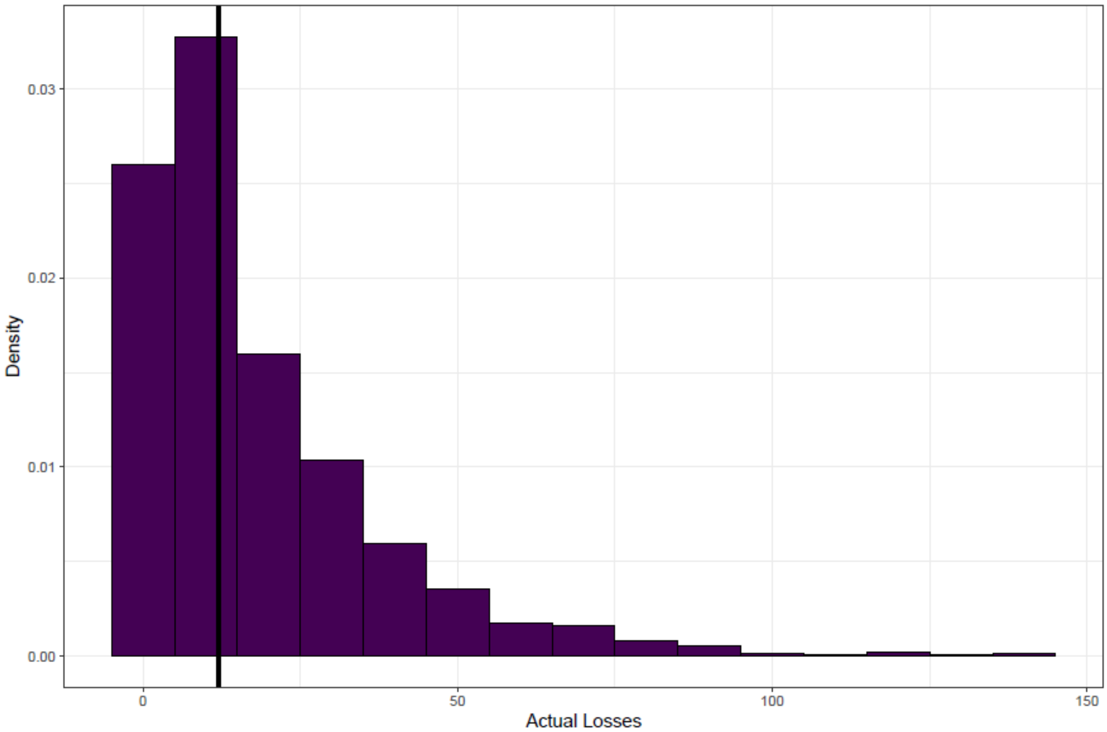

Figure 4 Histogram of the total losses distribution of birds at Crowlands Wind Farm. The black solid line indicates the median.

4 DISCUSSION

4.1 Searcher Efficiency

Results for the detection of both birds and bats is 100%, with 95% confidence that the true value is somewhere between 95% and 100%. This is consistent with other wind farm sites utilising dog/handler teams and searching roads and hardstands only. 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 small test sample for the human search component resulted in a mean detection of 78% with a large confidence range [40%, 98%] and is consistent with similar studies which have demonstrated a decrease in detection success by human observors with carcass size. The detection of large carcasses such as eagles can be assumed to be 1 on roads and hard stands for both human searches and dog searches. The use of dogs is particularly advantageous for small targets such as bats and small birds where evidence has shown that humans have low detection rates (Mathews et al. 2013) and it is therefore advantageous to engage dogs at wind farms surveys particularly in the detection of bats and small birds. The continued use of dogs at Silverton Wind Farm will provide the most robust survey method for maximising detection success.

4.2 Carcass Persistence

Carcass persistence was low at Silverton Wind Farm and appears to be similar to other dry climate wind farm sites which measure road and hardstand persistence only (personal experience). Mean removal at Silverton of 1.5 days for birds and bats combined is comparable to Crowlands Wind Farm in Victoria's north west which surveys roads and hardstands only, but not to other sites further south which measure the entire survey area. For example, the state-wide mean persistence for carcasses at wind farms in Victoria is 2.7 days [2.1, 3.4] for bats and 5.7 [4.8, 6.8] for birds and much higher (>280 days) for wedge tail eagles (Symbolix, 2020). The ability to detect carcasses on roads and hardstands is higher for both human and dog survey teams and so it stands to reason is also likely higher for scavenging animals. Additionally, limited food resources during the sustained period of drought within the region around Silverton Wind Farm may have made scavenging more desirable thus reducing carcass persistence. Reducing the survey interval from 3 to 2 days is one option to reduce the uncertainty of low persistence on bird and bat mortality estimates.

4.3 Carcass Searches

Overall mortality estimates for bats at Silverton Wind Farm is 95% confident that no more than 75 bats were impacted during the first year of monitoring. The average number of bats likely to have been impacted per turbine over the survey period is 0.6, with 95% confidence that less than 1.3 bats per turbine was impacted. This figure is low when compared to most other wind farms in Australia and overseas where ranges of bat impacts often exceed 8 to 9 bats per turbine per year. Biosis reported no significant change in bat diversity or activity from pre-construction through to the time of this study and thus the estimated impact for this site can be considered very low. The low number of carcass finds means that estimates are based on a limited data set, which adds a level of uncertainty in the estimations. Therefore, the assumption is that these figures could be either a true indication of a low impact to bats or that survey protocols may not be adequate for finding carcasses.

Similarly with birds, overall mortality estimates for birds at Silverton Wind Farm is low with 95% confidence that no more than 56 birds were impacted during the survey period. The average number of birds likely to be impacted per turbine per year is 0.3, with 95% confidence that less than 1 bird per turbine was impacted. These estimations are based on no finds during the survey period which is likely correlated to the low activity on the wind farm site during the same period. Bird activity was shown to have decreased since pre-construction most likely due to dry climatic conditions. The low impact measured during the survey period may be a reflection of the low usage of the site by birds or that survey protocols may not be adequate for finding carcasses.

Comparing figures estimated from the Silverton Wind Farmwith those elsewhere in Victoria and New South Wales wind farms is unlikely to offer any insights, due to the different climatic zone within which Silverton Wind Farm is located and the different bird and bat species that use the site. Survey effort in the initial six months of the monitoring period was high and correlated with decreased activity on the site and it would be expected that this would adequately detect carcasses if they were there to be found. It is likely that during this dry period that impacts at Silverton Wind Farm are low, as reported through mortality estimates. Increasing rain activity is likely to lead to an increase in bird and bat activity which may lead to a higher collision risk for this site. Understanding how changing climatic conditions influences collision risk for birds is necessary to develop robust estimates of the impact of Silverton Wind Farm on bird and bat populations.

4.4 Significant Impacts

Events considered or defined as a significant impact are outlined in section 3.1 and 3.2 of the endorsed Bird and Bat Adaptive Management Plan for Silverton Wind Farm. No species of concern were found and no impact triggers were reached during the 14 month survey period of this year 1 report and thus no significant impacts are recorded.

5. SURVEY DESIGN REVIEW

5.1 Rationale

In light of the low number of bird and bat carcasses detected during routine mortality surveys we asked our data specialists Symbolix to review survey design parameters in order to determine if the current survey protocols are adequate to detect a mortality event should it occur. When zero carcasses are detected during surveys it is necessary to ask two questions:

1. Is this indicative of very low mortality impacts?
2. Is the survey design adequate to detect mortality events if they occur?

Whilst activity of birds during the survey period was low, it was estimated that on average 18 birds and up to 56 birds were impacted across the site, however the survey effort did not detect any of these incidents during routine surveys. In order to better understand if impacts were very low we investigated the likelihood of detecting a carcass under different survey efforts.

5.2 Methods

Three survey options were compared against the current methods to determine if small changes in survey design could increase opportunities for mortality detections (Table 7). Comparisons were made using a Monte-Carlo simulation which generates simulated mortalities and comparing the probability of detection under the different search scenarios. Full methods to compare survey protocols can be found in Appendix 3.

Table 7 Alternative survey designs for comparison with existing survey design

Option 1 (current)	Option 2	Option 3	Option 4
14 turbines one month 15 turbines the next Pulse survey 2 days later 348 searches per year	29 searches per month Pulse search 2 days later (All 58 turbines over a 2 month period) 696 searches per year	All 58 turbines searched once per month (no pulse) 696 searches	58 searches once per month Pulse 2 days later at 15 turbines 876 searches per year

5.3 Results

5.3.1 Probability of Detection

For all scenarios, where bird and bat mortalities are low (less than 50) there is a large degree of variation in the proportion of finds which is to be expected when mortality events are rare. Above 50 mortality events the proportion of carcass detections become consistent although there is still a large scatter in the proportion found (see Figure 2, Appendix 2). Table 8 compares the best-fit probabilities for each survey design with option 4 having the highest probability of detecting carcasses, followed by option 3, option 2 and then option 1. Options 2, 3 and 4 are at least twice as successful in detecting carcasses then option 1.

Table 8 Percentage of bird and bat carcasses found for each survey option where mortalities exceed 50 per year. For rare species and low mortalities there is a lot more variation in the probability of detection.

Option	Bat (%)	Bird (%)
Option 4	12.0	7.5
Option 3	10.6	6.6
Option 2	9.7	6.2
Option 1	4.9	3.0

5.3.2 Probability of Finding Evidence

Under the different scenarios, we also explored the probability of finding at least one carcass if a [range of] small number of individuals were struck. This uses the same methodology as the probability of detection but asks the question in a different way. It is clear from Figure 5 that options 2, 3 and 4 are much better at finding evidence of an impact at low carcass counts than option 1 and that there is functionally very little difference between options 2, 3 and 4. Where counts are less than 10, all methods have less than a 50% chance of detecting a single carcass.

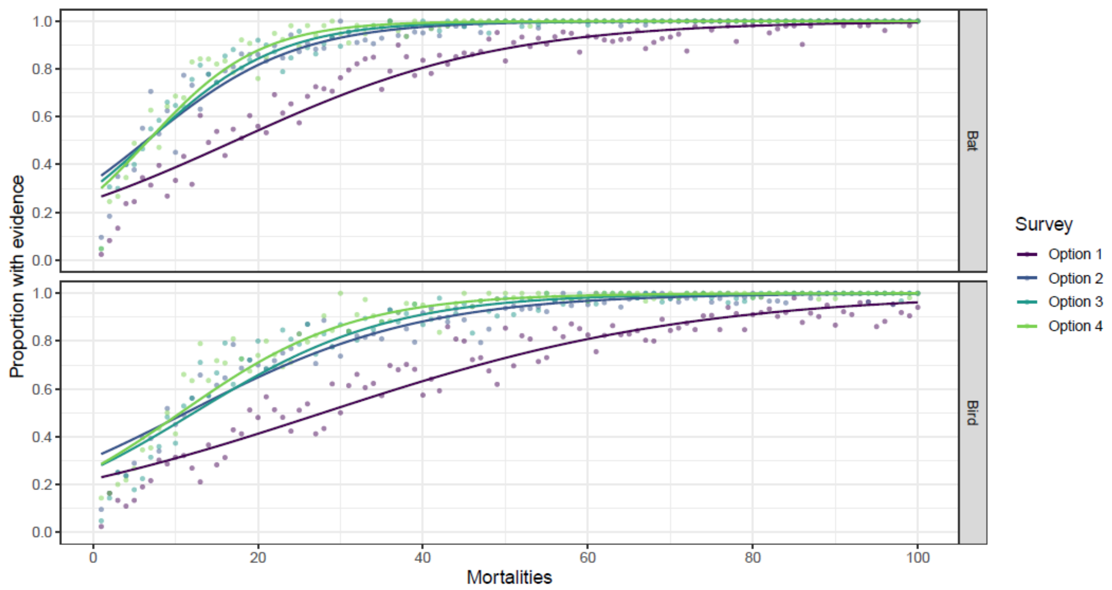

Figure 5 Probability of finding evidence given different number of mortalities under the different survey designs.

5.4 Implications

Moving from option 1 to any of the other survey options will at least double the probability of detection and increase the certainty around bird and bat mortality estimates at Silverton Wind Farm. Whilst option 4 is consider the best option, any of the alternatives are markedly better than the current survey design. At present there is only a 3% probability of detection for bird carcasses at Silverton Wind Farm and therefore a zero count of birds as detection during this survey period should not be unexpected. Moving to options 3 or 4 more than doubles the chance of detection for both birds and bats will provide more certainty that a zero count is actually representative of the impact and not a function of survey effort.

6. RECOMMENDATIONS

6.1 Searcher Efficiency

Searcher efficiency trials have demonstrated high detection for both birds and bats. Ongoing trials for searcher efficiency are conducted routinely on the dog and handler teams and are scheduled to occur in year 2 of this study. This will ensure on going quality assurance and to confirm that searcher efficiency has remained consistent throughout the program.

6.2 Carcass Persistence

The carcass persistence trials undertaken at Silverton Wind Farm will be repeated in the second year of the study in Spring and Autumn as outlined in the BBAMP. Additional data may assist in separating the persistence times of birds and bats carcasses and provide more robust estimates which helps reduce uncertainty in final estimates.

6.3 Mortality Survey

Reported mortalities for both bats and birds are low relative to reported impacts from elsewhere in Australia (Symbolix 2020, personal experience). It is likely that the dry conditions contributed to low site usage of birds and bats during the survey period due which lead to lower collision rates recorded. Due to increased water in the landscape, this may not hold true for the second year of mortality surveys. The low probability of detection of the current survey design (4.9% for bats and 3.0% for birds) and the low number of collisions estimated for the Silverton Wind Farm means that bird and bat carcass detections will be rare events and the chance of finding rare species if impacted are significantly lower. Increasing survey effort based on the options presented will increase the probability of detection significantly and provide confidence that the estimated mortality is a true representation of the impact at Silverton Wind Farm. The reported options for detection probability suggests that searching every turbine provides the best increase in detection probability (options 3 and 4) and that the additional pulse surveys at 15 turbines in option 4 should also be considered if possible.

7. REFERENCES

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8. APPENDIX

1. Section 4 BBAMP summary table of completed actions
2. Symbolix Report: Silverton Wind Farm Mortality Estimate Year 1
3. Symbolix Report: Assessment of survey designs at Silverton Wind Farm

ELMOBY ECOLOGY

Appendix 1

BBMAP Section 4 Table	Action	Measure	Responsible Party	Status
4	Engage dog handler or human observer team(s) with experience at undertaking carcass searches at wind farms.	Demonstrate consideration of both dog handler or human observer search options	Dog teams engaged by GE renewables	completed
4	Train dog-handler / human observer teams on how to undertake the carcass searches and collect the requisite information	Record the date of induction	Skylos Ecology (previous experience)	completed
4	Undertake turbine collision carcass searches at 29 turbines (15 turbines in one month, 14 turbines in the next month) using a dog-handler team or human observers	Documented number of carcasses detected for each species. Documented search frequency and effort.	Skylos Ecology undertook and documented search effort	completed
4	Collection, recording, storage & carcass disposal	Using turbine mortality data sheet	Skylos Ecology	completed
4	Review carcass search regime	Submission of report to OEH	Skylos Ecology in conjunction with advice from Biosis, Elmoby Ecology and Symbolix	completed
4	A freezer will be available for the purpose of storing bird and bat carcasses	Correspondence with Australia Museum	Skylos Ecology	completed
4	Apply for a permit under the *Biodiversity Conservation Act 2016* to collect and store bird and bat carcasses	Timely permit application to OEH under the *Biodiversity Conversation Act 2016*	Unnecessary due to section Biodiversity Conversation Act section 2.8 Acts authorised under other legislation etc, 1(a)	completed
4	Identify and collect all dead bird and bat carcasses upon discovery and complete data sheets for each carcass collected	Completed turbine mortality data sheets for all collected bird and bat carcasses, logged in the annual report	Skylos Ecology	Completed / ongoing

4	Appropriately label and store bird and bat carcasses	Documented notification correspondence to OEH and the Australian Museum	Skylos Ecology	Completed / ongoing
5	Implement scavenger trials	Completed carcass persistence trial data sheets, calculation of average persistence times	Skylos Ecology and Symbolix	Completed / ongoing
6	Undertake searcher efficiency trials	Trial dates and findings are recorded and reported in the annual report, and used to assist in the review of the monitoring program	Elmoby Ecology	Completed / ongoing
7	Training of site personnel on procedures for bird and bat carcasses found incidentally	Inductions have been completed for all site personnel and date of attendance has been recorded.	GE Renewables	
7	Photography of incidentally encountered bird and bat carcasses; completion of relevant data form	Completed dead or injured bird/bat data sheet, also recorded in the annual report	Skylos Ecology and Elmoby Ecology	Completed / ongoing

Appendix 2

Silverton Wind Farm Mortality Estimate - Year 1

Prepared for Elmoby Ecology, 27 January 2021, Ver. 1.1

This report outlines an analysis of the mortality data collected at the Silverton Wind Farm from 2019-11-18 to 2020-12-09. The analysis is broken into the three related components below:

- Searcher efficiency / detectability – estimated from trials in May 2020 and November 2020
- Scavenger loss rates – consisting of trials in May 2020 and November 2020
- Mortality estimates - based on monthly surveys at 58 turbines, from 2019-11-18 to 2020-12-09. Note - two extra months of survey were added to the first year of analysis due to border restrictions, compared to Version 1.0 of this report.

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

Available data

The data analysed was collected, verified and provided to us from 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 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.

[1] Silverton YEAR 2 DEC 2020.xlsx, Silverton Wind Farm Survey Areas.zip, Silverton Wind Farm Turbine Locations.zip

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

Two searcher efficiency trials were held (2020-05-11 and 2020-11-05). A range of carcass sizes and species types were used. White-striped Freetail Bats and Eastern Falsistrelles were mainly used as the bat archetype, while bird carcasses included Peregrine Falcons, Nankeen Kestrels, and Currawongs. Canine and human searchers were used.

The detectability trials used both bird (34 replicates) and bat carcasses (47 replicates). We found no evidence that searcher efficiency differed between birds and bats via AICc selection, and thus have aggregated them in the mortality estimate. Similarly, we found no evidence that searcher efficiency differed between the surveys held on 2020-05-11 and 2020-11-05. AICc selection did, however, suggest that the most parsimonious model was one that differentiated between canine and human searchers. We thus have treated them separately in the mortality estimate.

Table 1 summarises the result.

Detectability using canine searchers is 100%, with a 95% confidence interval of [95%, 100%]. Using human searchers, detectability is 78% with a 95% confidence interval of [40%, 97%].

Table 1: Detection efficiencies for canine and human observers.

Variable	Dog	Human
Number found	72	7
Number placed	72	9
Mean detectability proportion	1	0.78
Detectability lower bound (95% confidence interval)	0.95	0.4
Detectability upper bound (95% confidence interval)	1	0.97

Scavenger efficiency

Scavenger efficiency trials were conducted in May 2020 and November 2020. They used a mixture of bats (five replicates), bat proxies (mice; 15 replicates), and birds of various sizes (20 replicates). Cameras were used, which took photos every hour.

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 no evidence (via AIC scores) that birds and bats/bat proxies have significantly different scavenger rates. Therefore, in the following mortality estimate, bird and bat scavenger rates are aggregated.

Figure 1 shows a survival curve fitted to the combined cohort of bats and birds. 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 12% to 41% of carcasses to remain after ten days with the expectation being around 22%.

Under these assumptions, the mean time to total loss via scavenge is 1.5 days, with a 95% confidence window of [0.8, 3] days.

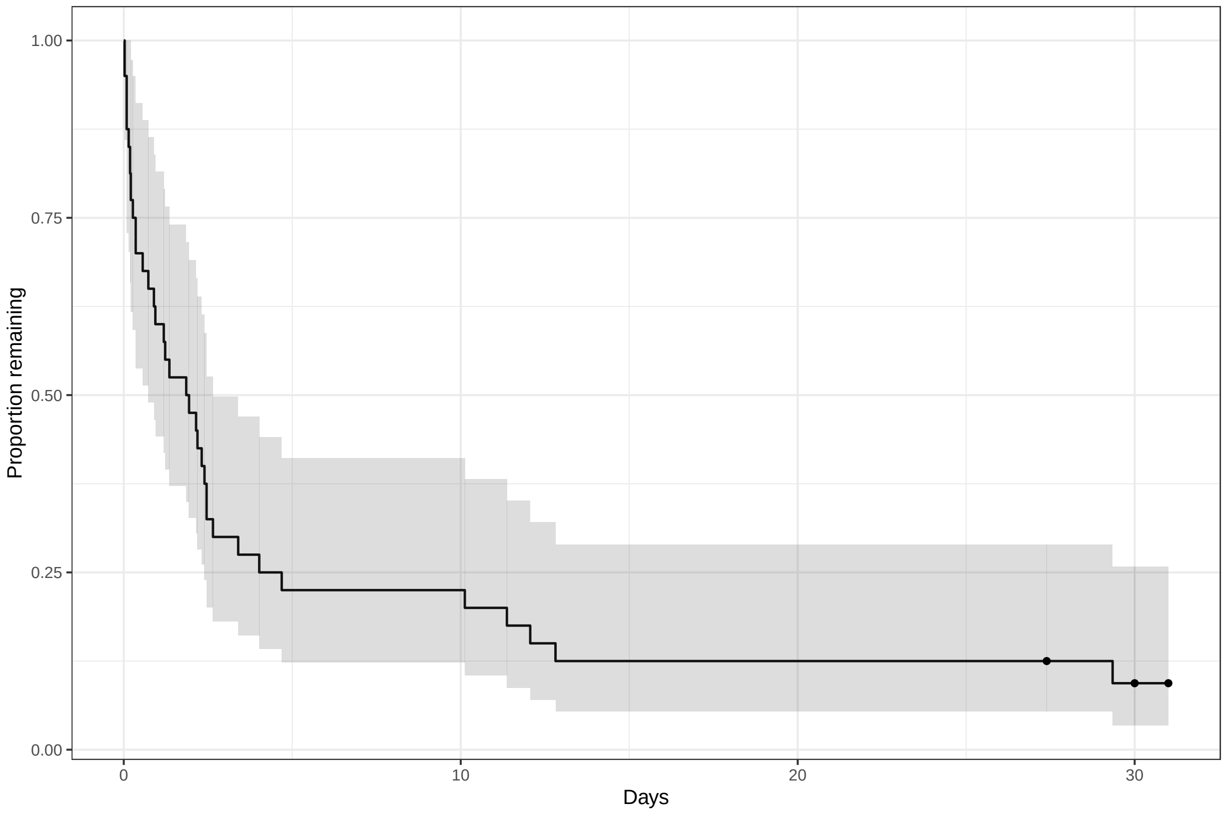

Figure 1: Combined survival curves for birds and bats, with 95% confidence interval shaded.

Due to results in Stark and Muir (2020), we have used a log-normal shape, which has been found to accurately describe the scavenger profile of carcasses in Victoria. This corresponds to an "olfactory" profile. We also tested the standard exponential shape, but log-normal was found to provide a better fit to the data (via AIC selection).

Carcass search data

The mortality estimate was based on a dated list of turbine surveys. The survey frequency is summarised in Table 2. All 58 turbines were surveyed. Surveys occurred twice each month, with the second pulse survey occurring three days after the first. Searches occurred in the hardstand and road areas around the turbines out to 70 metres.

Table 2: Number of surveys per month.

Date	Number of surveys
2019 Nov	116
2019 Dec	116
2020 Jan	116
2020 Feb	116
2020 Mar	116
2020 Apr	116
2020 May	28
2020 Jun	30
2020 Jul	28
2020 Aug	30
2020 Sep	28
2020 Oct	30
2020 Nov	28
2020 Dec	30

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 Silverton Wind Farm from 2019-10-18 to 2020-12-09 (we allow for collisions to occur up to a month prior to the first survey).

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 58 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 (2019-11-18) and until the final surveyed date (2020-12-09).
- 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 a log-normal scavenge shape.
- We took scavenge loss and search efficiency rates as outlined above.
- All 58 turbines surveyed and were searched out to a 70 metre radius in their hardstand / road zone only. We estimated the "coverage factor" for the survey – i.e. the total fall zone surveyed for birds and bats (using estimates of fall zone from Hull and Muir (2010), and coverage factor calculations from Huso, Dalthorp, and Korner-Nievergelt (2017)). In calculating the average coverage factor for each species, we also took into account the proportion of hardstand / road search area actually searched and the differences in detectability in surveys performed with human versus canine observers. Taking into account the coverage factor, proportion of hardstand / road search area actually searched in each survey, and differences in detectability in surveys performed with human versus canine observers, the average detectability was 40% for bats and 22% for birds.

Mortality projection results

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

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

Species	Bat
gould's wattled	1
inland free-tailed	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 formal survey area).

Species	Date
australian owlet-nightjar	2019-12-27
nankeen kestrel	2019-12-28
wedge-tailed eagle	2020-03-24
gould's wattled	2020-04-16
white-striped freetail (presumed)	2020-05-08
white-striped freetail	2020-06-11
wedge-tailed eagle	2020-10-08
white-striped freetail	2020-11-04
wedge-tailed eagle	2020-11-04
little button quail	2020-11-06
unknown	2020-12-06
masked woodswallow	2020-12-09

Bat mortality estimate – results

During the first year of surveys a total of 2 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 33 and a median of 29 bats lost on site over the fourteen 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 33 bats over the survey period, and are

95% confident that fewer than 75 individuals were lost.

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

0%	50% (median)	90%	95%	99%	99.9%
3	29	61	75	105	137

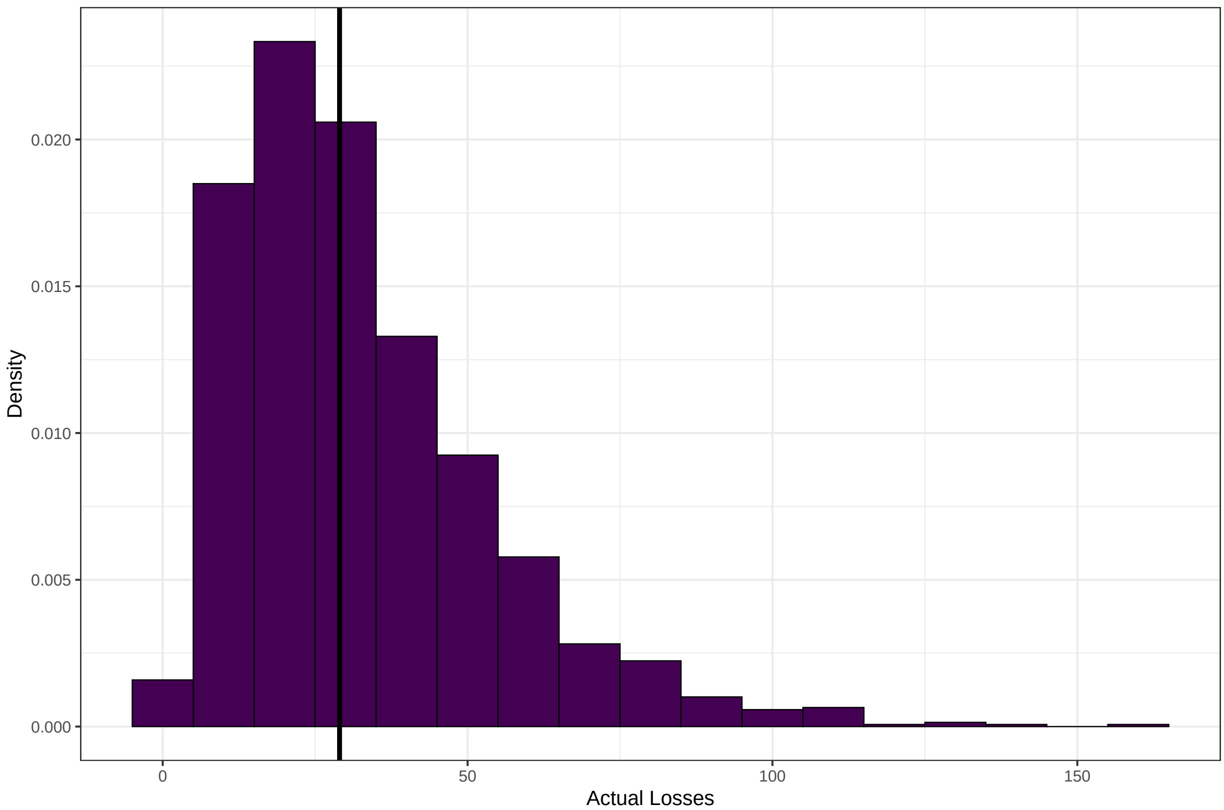

Figure 2: Histogram of the total losses distribution (bats), given 2 were detected on-site. The black solid line shows the median.

Bird mortality estimate - results

During the first year of surveys a total of 0 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 18 and a median of 12 birds lost on site over the fourteen 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 18 birds over the survey period, and are 95% confident that fewer than 56 individuals were lost.

Table 6: Percentiles of estimated total bird losses over the one year of survey period.

0%	50% (median)	90%	95%	99%	99.9%
1	12	43	56	87	135

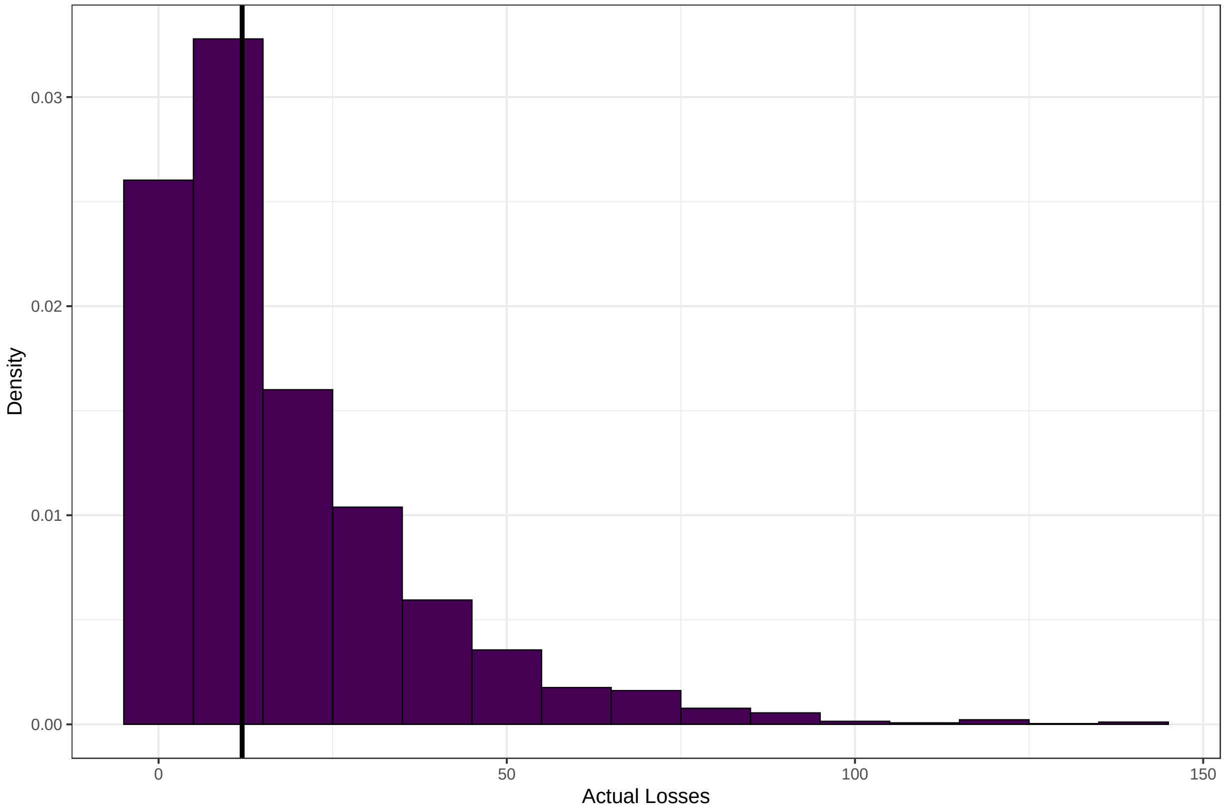

Figure 3: Histogram of the total losses distribution (birds), given 0 were detected on-site. The black solid line shows the median.

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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Appendix 3

making your data work harder

To: Tracy Lyten
Skylos Ecology
Via email

Ref #: ELMSILV20210216
Date: 16 February 2021
CC: Emma Bennett

Re: Assessment of survey designs at Silverton Wind Farm

Dear Tracy,

This letter provides statistical advice on the bird and bat carcass monitoring program at Silverton Wind Farm, in western New South Wales. While the existing program is sufficient for mortality estimates, we understand the end-client would like to explore options to increase the overall probability of detecting carcasses.

We analyse four survey design options (the current program, and three alternatives) for:

a) the overall probability of detecting a carcass; and
b) the probability that some evidence of collision is found.

Survey designs

The four survey designs (also referred to as Options) are summarised below. All surveys only involve searches on the hardstand and road surrounding the turbine base, out to a maximum radius of 70 metres.

Silverton Wind Farm contains 58 total turbines.

Option 1

Option 1 is the current survey design. It involves searching 14 turbines one month, and 15 turbines the next month, with a pulse search at each searched turbine 2 days later. This comes to a total of 348 searches per year.

We have assumed that Option 1 will continue in the same fashion as in May last year, which is the **same** 14 and 15 turbines being searched in alternating months.

Option 2

Option 2 has 29 turbines searched per month, with a pulse search 2 days later. This comes to a total of 696 searches per year.

We have assumed that the 29 turbines alternate between months, i.e. the first 29 are searched in January, then the second 29 are searched in February, then the first 29 are searched in March, and so on.

Option 3

Option 3 has all 58 turbines searched once per month. This option has no pulse. This comes to a total of 696 searches per year.

Option 4

Option 4 has all 58 turbines searched per month. Additionally, there is a pulse search 2 days later at 15 turbines. This comes to a total of 876 searches per year.

Methodology and assumptions

Overview

There is no 'golden rule' governing the optimal frequency of searches. For example, we are not trying to determine the difference between classes, so a power analysis is not applicable.

We can use simulation methods to estimate the proportion of carcasses that will be found given this survey design. The same method can help us understand the likelihood of a true absence by simulating the frequency of the search protocol missing all mortalities.

It's worth remembering that the mortality estimate itself does not require coverage of all turbines and dates - only that the sample is chosen in a way that does not fail the assumptions of the Horvitz-Thompson estimator.

In this exercise we are exploring the two questions:

a) What is the overall probability that we will detect a find, given a proposed design?
b) Is absence of evidence (of collision) evidence of absence?

In the latter case we explore this by reporting the percentage of simulations that 'found' at least one carcasses, for different numbers of actual mortalities. If some (small) number of collisions occur, what is the chance we will detect it? Could modifications to the survey design substantively impact this chance?

Methods

To allow for survey protocols with non-standard intervals between searches, we developed a Monte-Carlo simulation method.

The Monte-Carlo simulation generates a representative coverage of the phase space influencing the probability of detection. We simulate mortalities at the wind farm, and then report on the number of carcasses found under the search protocol. This provides us with all the information we need to answer our two questions.

For full details on the algorithm used see Stark and Muir (2020). A summary of the algorithm flow can be found in Figure 1.

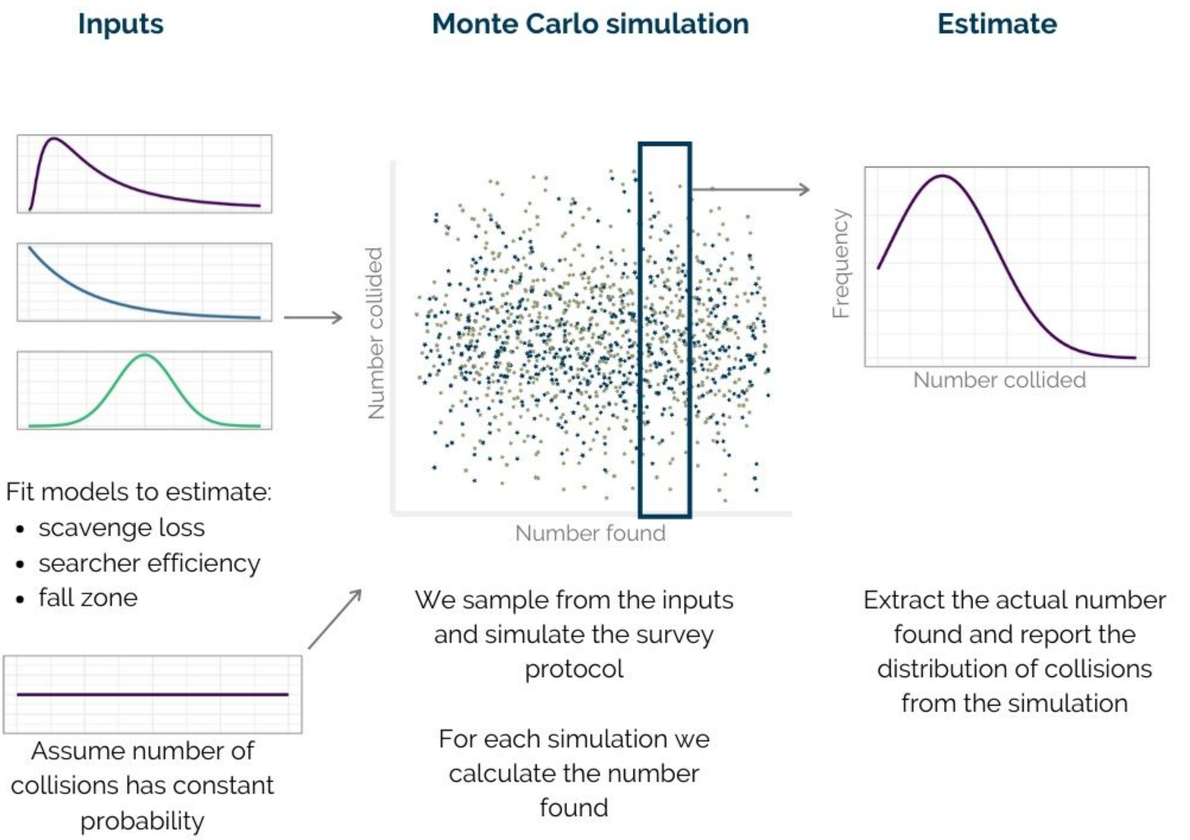

Figure 1: Schematic showing the application of the Monte-Carlo method to simulate the phase space of possible collisions and subsequent carcass finds. The inputs are based on empirical distributions estimated from field trials.

Statistical assumptions

- We used searcher efficiency and scavenger rate results from the year 1 mortality report (Symbolix 2020).
- Canine searchers only are used the simulation.
- We retain the restriction of roads and hardstand search areas. The "coverage factor" (the proportion of the fall zone of birds / bats covered by the search area) was calculated using the methods of Hull and Muir (2010) and Huso, Dalthorp, and Korner-Nievergelt (2015).

Results

Overall probability of detection

Figure 2 shows the simulation results. On the x axis we have the true number of mortalities; each black point gives the proportion of those mortalities found (for that particular simulation). The horizontal line is the "best fit" convergence probability.

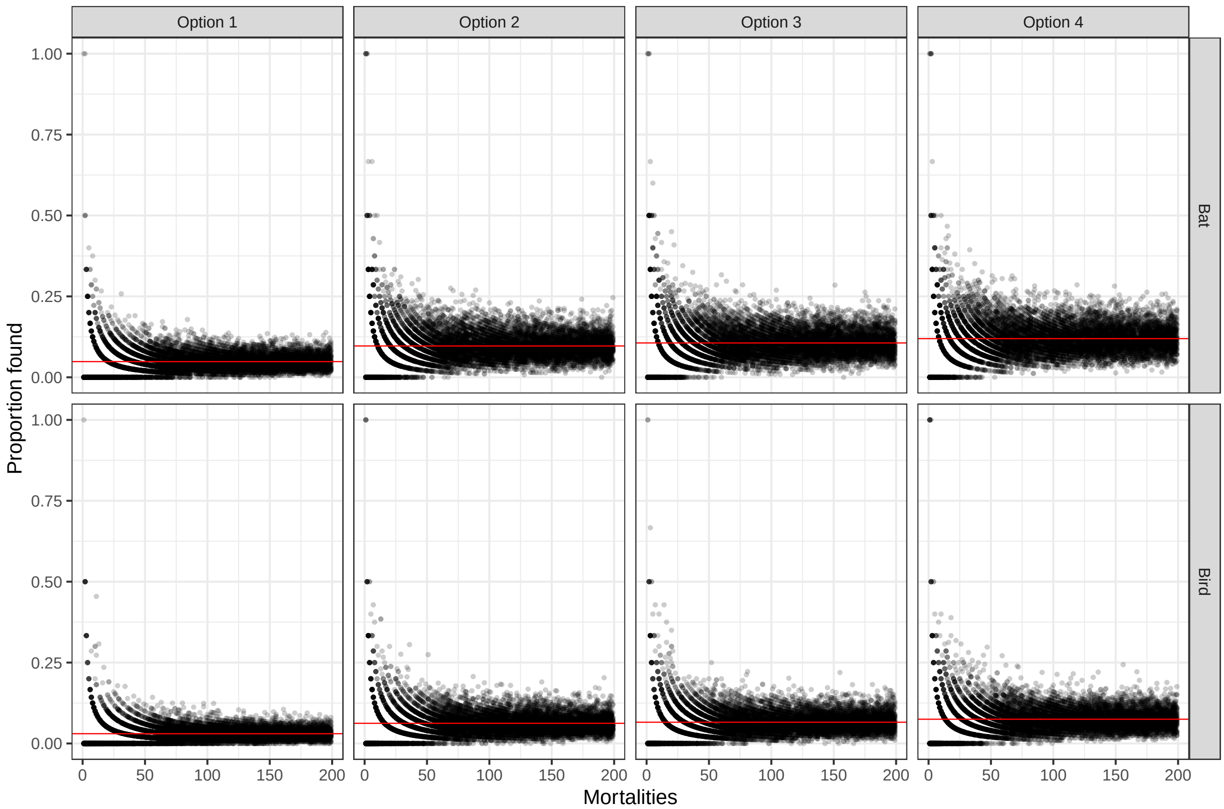

Figure 2: Probability of detecting a carcass (y axis) against the number of mortalities.

We can see that for all Options, for low numbers of mortalities (less than 50), there is a large degree of variation in the proportion of finds. Above this value, the proportion settles to a constant value. However, there is a still a large degree of variation between simulation runs (as we can see from the scatter around the red line) which is around 5 percentage points in Option 1, and 10 in the other Options.

Table 1 compares the best-fit probabilities (the horizontal red lines) for each survey design. Option 4 has the highest probability, followed by Option 3, Option 2, and finally Option 1. We can see that Options 2, 3, and 4 are of the order twice as "good" as the current Option 1 (if we take it that "good" means maximising the probability of detection).

Table 1: Percentages of bat and bird carcasses found, for each survey option.

Option	Bat (%)	Bird (%)
Option 4	12.0	7.5
Option 3	10.6	6.6
Option 2	9.7	6.2
Option 1	4.9	3.0

Note that these probabilities only apply at an overall level - for rare species with expected low mortalities, there is a lot more variation in the chance that you find the carcass.

Probability of finding evidence

In this section we look at the probability that you find evidence - i.e. if some number were struck, what is the chance that you find at least one carcass? We use the same simulated data as in the above section, but analyse it in a slightly different way.

Figure 3 shows the probability of finding evidence of mortality (y axis) given varying numbers of mortalities (x axis). The points are results from the simulation, with the lines coming from a smoothing GAM fit (to aid the eye). It's immediately evident that Options 2, 3, and 4 are more effective at finding evidence of mortality, compared to Option 1. While Option 4 appears to be fractionally superior compared to Options 2 and 3, there is little practical difference between them.

For low numbers of mortalities (less than 5 bats, or less than 10 birds), all survey designs have a less than 50% chance of finding evidence of mortality. Figure 4 zooms in on these low numbers of mortalities, for clarity of the curve. The implication of this is: the mortality estimation survey program on its own is not sufficient for providing evidence of mortality for rare species. Other streams of evidence would be required in conjunction with the program.

As the number of mortalities increases, the probability of finding evidence increases towards 100%. We can see from Figure 3 that by the time we have 50 mortalities, the chance of evidence is close to 100% for Options 2, 3, and 4, while it takes close to 100 mortalities for the same chance of evidence for Option 1.

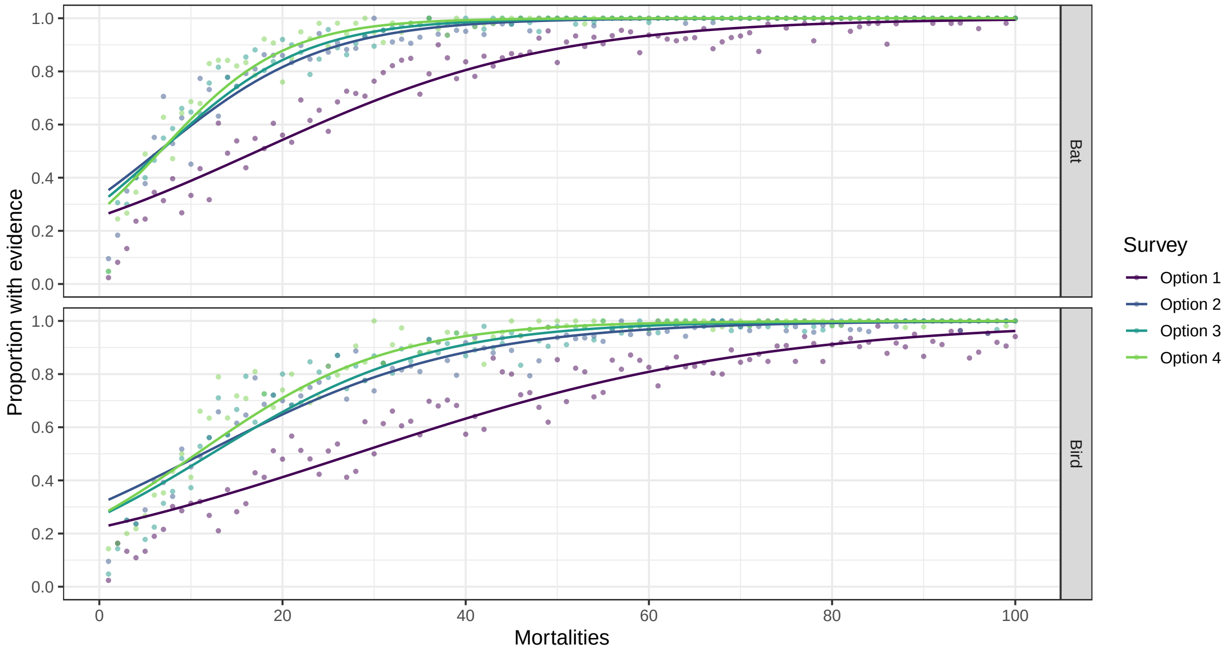

Figure 3: Probability of finding evidence given different numbers of mortalities, under the various survey designs.

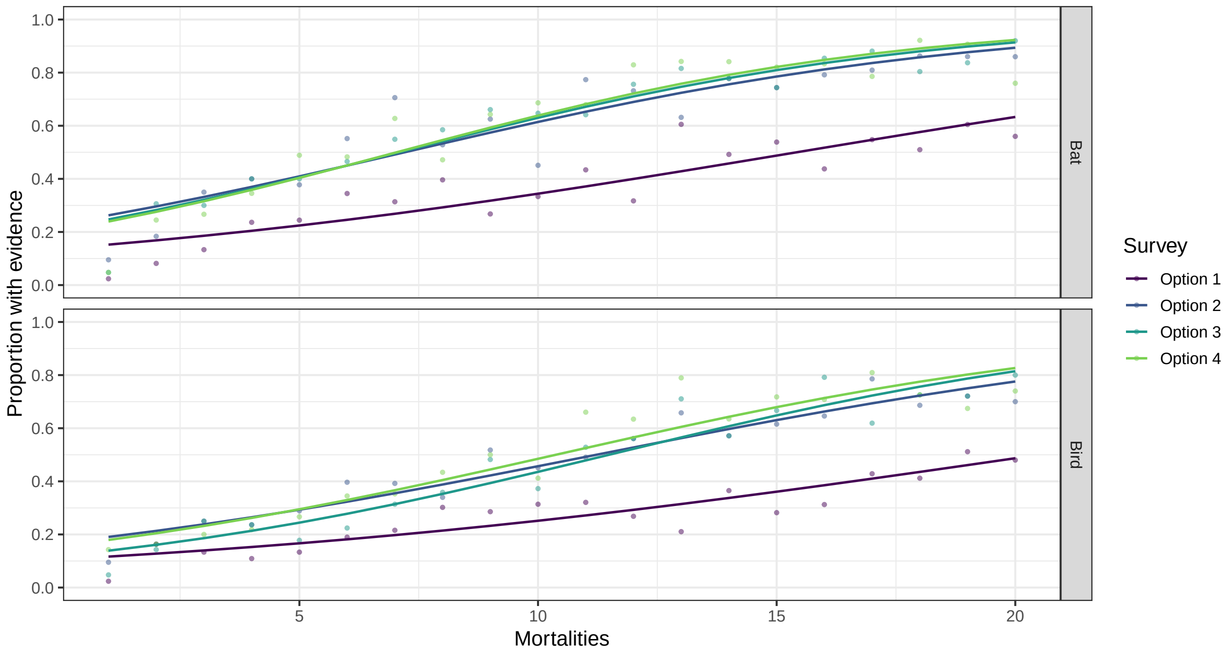

Figure 4: Zoomed-in section of Figure 3 for less than 20 mortalities, with the GAM smoother refit.

Conclusions and recommendations

In terms of overall probability of detection, Option 4 has the highest probability of detection of the competing designs, followed by 3, and then 2. This applies to both birds and bats - moving from Option 1 to any of the other options will double the overall probability of detection, at least.

In terms of probability of evidence, again Option 4 is the best design - however, there is not a lot distinguishing it from 2 and 3. Options 2, 3, and 4 are markedly superior to Option 1.

We recommend moving from the current survey design of Option 1, to one of the alternatives (Options 2, 3, or 4). If possible, Option 4 is preferred, due to its higher performance - however, the three alternatives are all significantly better than the current design, and are generally comparable. Therefore Options 2 and 3 would also be acceptable choices.

If you have any further questions or comments, please do not hesitate to contact us.

Regards,

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