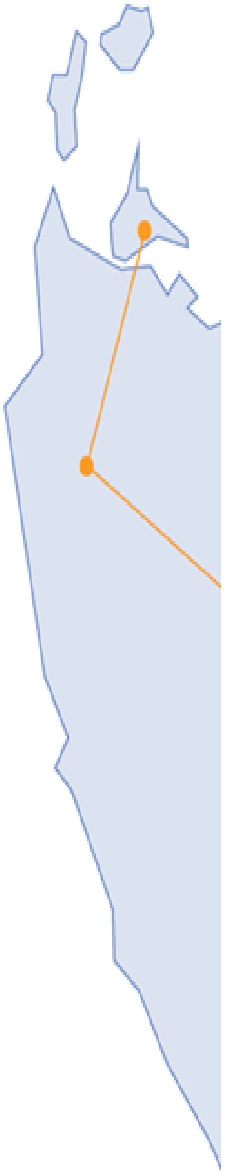
UPC\AC Renewables
AUSTRALIA

Jim's Plain & Robbins Island
Renewable Energy Parks



Robbins Island Renewable Energy Park

Appendix K

Eagle Flight Analysis

UPC Robbins Island Pty Ltd

Robbins Island Eagle Flight Analysis

Alex Jackson

Ver. 1.0

Submitted to Nature Advisory

making your data work harder

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Elizabeth Stark Date

Limitation: This report has been prepared in accordance with the scope of services described in communications between Symbolix Pty Ltd and Nature Advisory. Any findings, conclusions or recommendations only apply to the aforementioned circumstances and no greater reliance should be assumed or drawn by Nature Advisory.

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1 Summary

This report summarises our analysis of eagle flight path data at Robbins Island, Tasmania. Nature Advisory collected Tasmanian Wedge-tailed Eagle (TWTE) and White-bellied Sea Eagle (WBSE) flight tracks from Feb 2018 to Nov 2019 at 12 fixed locations around the island.

This report provides an overview of the data used for analysis, and an assessment of eagle flight activity. The aim of this work is to provide quantitative flight activity analysis that can be considered as part of an ecological risk analysis.

To do this, we provide the following:

- A summary of the survey effort, and the recorded eagle observations (Section 2).
- A distance corrected flight activity rate, in flights per hectare per hour. We use distance correction models (Buckland et al. 2008) to obtain an overall estimate of eagle flight density, accounting for the fact that it's harder to spot flights that are further from the observer (Section 3.1). This measure does not take into account spatial variation in activity, but provides a measure of average activity over the whole study area.
- A spatial map of eagle utilisation over the Robbins Island (Section 4) site. This complements the previous measure by providing information on the spatial variation, but not on the likelihood of a flight in the first place. Together these measures may be incorporated into a qualitative or quantitative assessment of the overall collision risk as required.

1.1 Summary of results

This analysis is based on 229 person hours of observation in 673 observation shifts, from Summer 2018 to Spring 2019. 125 valid flight tracks were recorded - 40 independent Tasmanian Wedge-tailed Eagle tracks, and 85 independent White-bellied Sea Eagle tracks. 84% of shifts (563 total) did not record a flight track.

Some observations recorded more than one bird flying together. In total - 63 Tasmanian Wedge-tailed Eagles, and 106 White-bellied Sea Eagles were observed.

The encounter rate (number of observations per hour before distance correction) was 0.275 flights per hour for Tasmanian Wedge-tailed Eagles. As a comparison, a similar study at Low Head Wind Farm recorded 0.227 flights per hour (Symbolix 2017), and Cattle Hill Wind Farm observed 0.4 flights per hour for the same species (Hydro Tasmania Consulting 2010).

The encounter rate for White-bellied Sea was 0.463 flights per hour. The encounter rate for this species at Low Head Wind Farm was 0.058 flights per hour. It was not recorded at Cattle Hill Wind Farm.

The key findings regarding activity rates are (Section 3.1):

- The average effective detection range (EDR) is 1005 metres for both species of eagle.
- The overall, distance-corrected activity on-site is between 0.00093 to 0.0016 flights per

hectare per hour for White-bellied Sea Eagles. For Tasmanian Wedge-tailed Eagles, the activity is between 0.00044 to 0.00073 flights per hectare per hour. These values are reported to 95% confidence.

- This is a similar order of magnitude to the distance corrected activity rates at the Low Head Wind Farm study (Symbolix 2017). That study found average global flight rates of 0.00044 flights per hectare per hour (both species combined). Distance correction was not part of the Cattle Hill Wind Farm Assessment.

The spatial variation in activity patterns was investigated using utilisation maps (Section 4). Overall, the utilisation patterns throughout the site suggested uniform usage, noting the TWTE shows preference towards the central and south-west regions.

2 Data overview

In this section, we describe the survey effort to provide an independent validation of the survey methodology provided by Nature Advisory. We also provide a summary of the field data (pre-analysis).

Note that “WTE” (referred to in some Figures, for example) always refers to the Tasmanian Wedge-tailed Eagle.

2.1 Pre-processing

Shift and observation data was provided by Nature Advisory in Excel format, and raw flight tracks were provided as shape files.

We briefly outline pre-processing steps taken:

- **Observation sheet**: a number of records were not valid flights (e.g. perched birds or noted outside formal surveys). These were flagged by the Nature Advisory team as “incidental” or “exclude” in the `EXCLUDE` field. We removed these records from the analysis dataset.
- **Flights shape file**: three records (two Brown Goshawks and a Brown Falcon) were removed.
- **Flights shape file**: if the given species misaligned with the observation sheet record, the observation sheet was taken to be the master.
- **Flights shape file**: the spacing between points on the flight traces were re-spaced so each GPS point was four metres apart, while maintaining the same line shape.

2.2 Survey effort

Table 1 summarises the survey effort. The hours per season are roughly constant, with the exception of summer 2018 and spring 2018, which have lower hours.

Table 1: Summary of survey effort.

Season	Year	Surveys	Duration (HH:MM)	Start	End
Summer	2018	40	14:20	2018-02-09	2018-02-11
Autumn	2018	96	32:50	2018-05-06	2018-05-11
Winter	2018	96	32:47	2018-07-10	2018-07-14
Spring	2018	71	23:55	2018-10-06	2018-10-09
Summer	2019	96	32:01	2019-02-17	2019-02-21
Autumn	2019	97	32:30	2019-05-25	2019-05-30
Winter	2019	83	28:20	2019-08-18	2019-08-30
Spring	2019	94	31:48	2019-11-16	2019-11-21

Rounding to the nearest hour, there were 229 hours of survey over the period from 2018-02-09 to 2019-11-21.

Figure 1 shows the locations of the different observation points. They are spread evenly across the island.

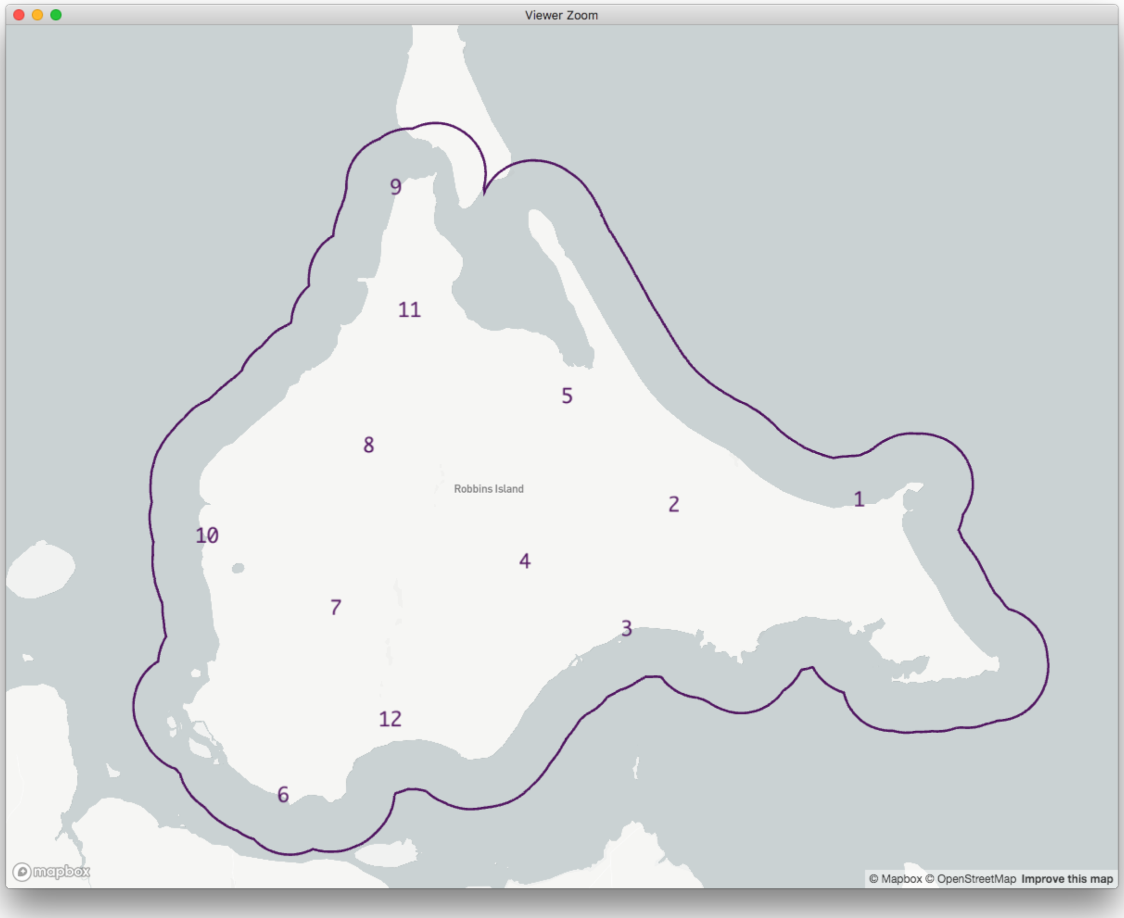

Figure 1: Observer locations (numbers) overlaid on the study error (boundary line).

Table 2 summarises the number of hours of survey effort per location. The spatial coverage over the island is also even.

Table 2: Hours by observer location.

Observer location	Hours
1	19.5
2	21.2
3	19.9
4	19.0
5	19.8
6	19.2
7	19.7
8	19.8
9	16.6
10	18.6
11	17.3
12	17.9

Figure 2 shows the coverage by time of day, where the frequency is the number of surveys held. We can see from this plot that the coverage between 8am and 5pm is good, and demonstrates adequate coverage of daylight hours.

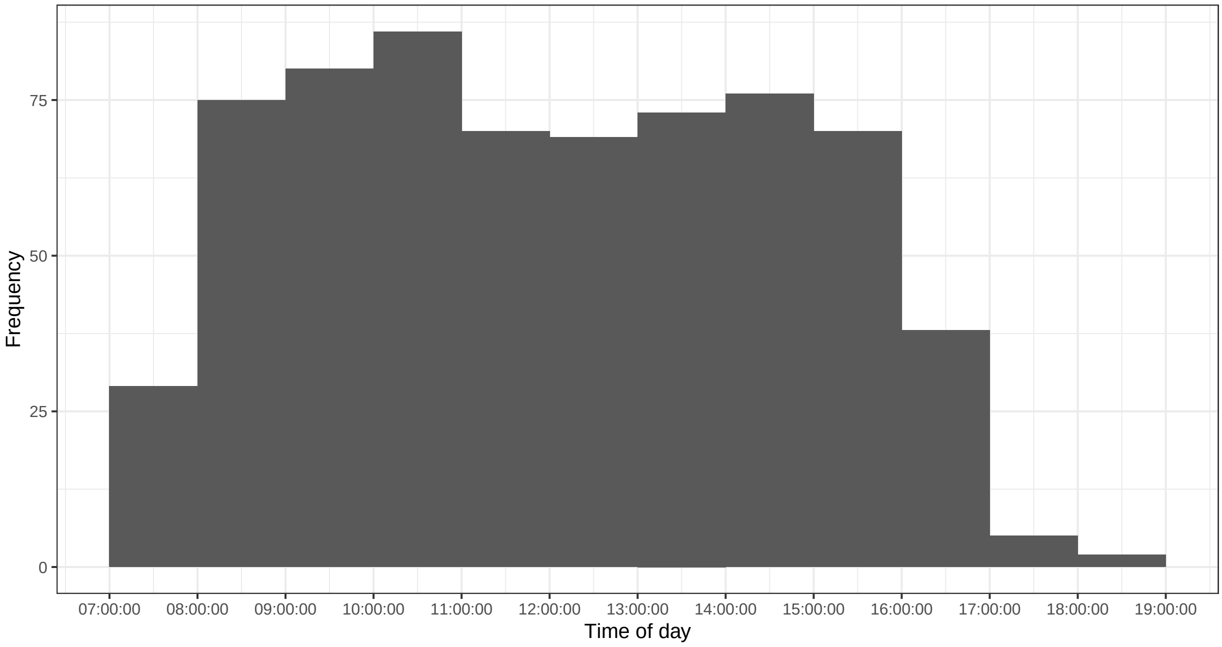

Figure 2: Time-of-day coverage of the surveys.

2.3 Observations

Figure 3 shows the raw flight paths, coloured by species. This only includes formally observed flights.

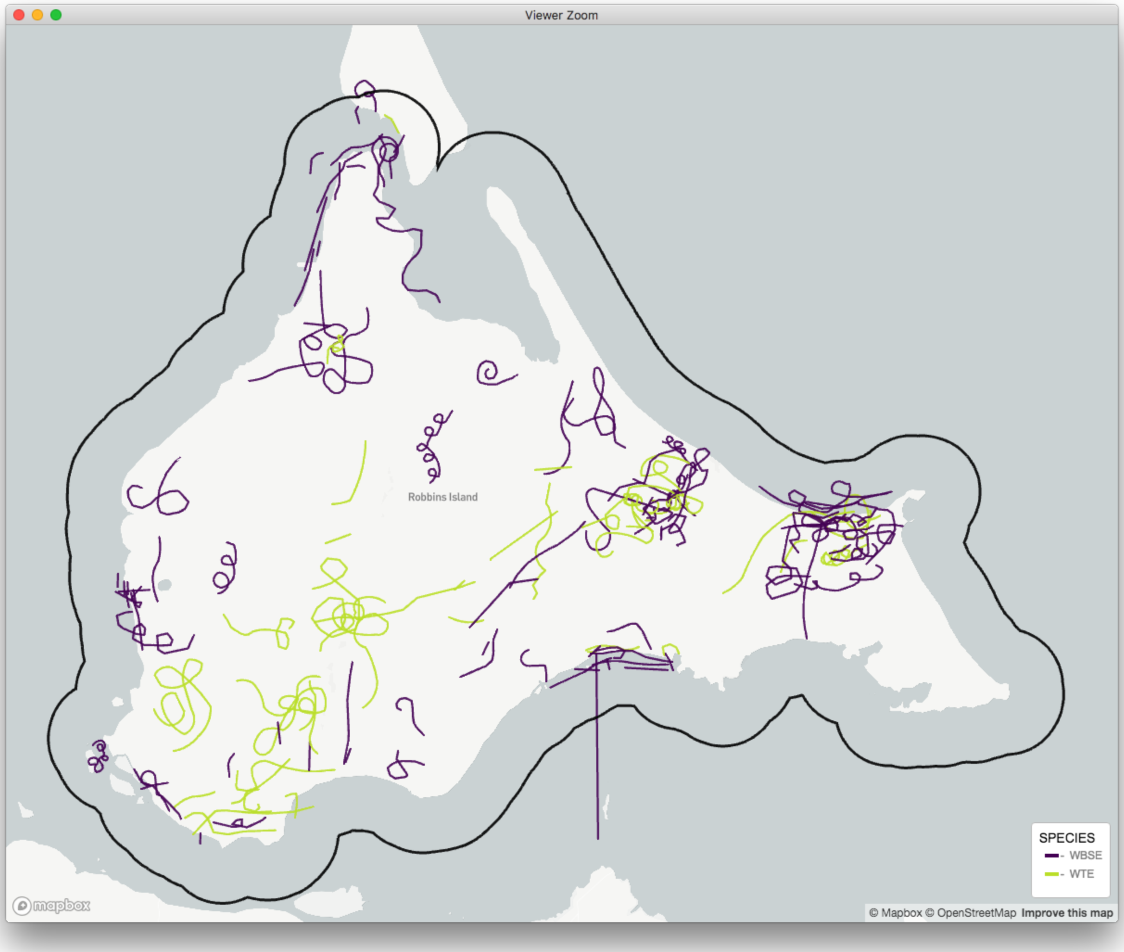

Figure 3: Flight paths by species.

Table 3 summarised the number of formally observed flights per season, split by species (WBSE = "White-bellied Sea Eagle", WTE = "Tasmanian Wedge-tailed Eagle"). Generally, higher counts of WBSEs were reported.

Table 3: Flights observed per season in formal surveys. Note that a single observation may include multiple birds on the same flight (path).

Season	Year	WBSE	WTE
Summer	2018	3	8
Autumn	2018	20	14
Winter	2018	15	10
Spring	2018	6	2
Summer	2019	5	15
Autumn	2019	26	5
Winter	2019	18	4
Spring	2019	13	5

There were also a number of incidental (not observed in a formal survey) or otherwise excluded sightings (usually because the bird was perched). These were not included in any further analysis, but are reported here for completeness in Table 4.

Table 4: Sighted eagle flights which are not included in formal analysis.

Reason	WBSE	WTE
incidental	31	23
perching/other	8	6

Figure 4 shows the distribution of times of day when flights were first observed. The distribution is even through the period of surveyed times. The median flight duration was 2 minutes.

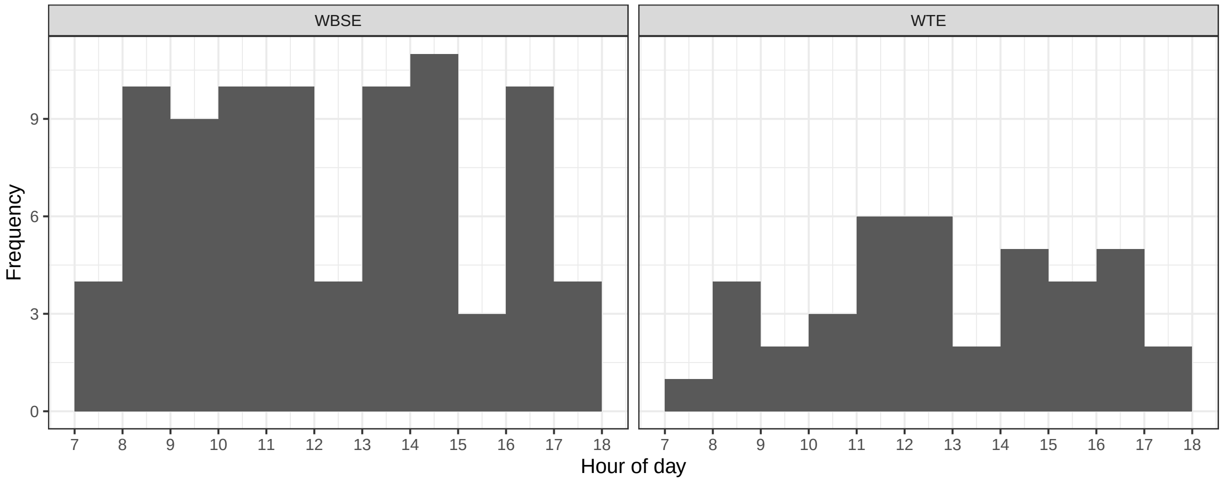

Figure 4: Time of day when eagles were first observed.

Figure 5 shows the flight heights (at point of first observation) of the eagles. For both WBSEs and TWTEs, 90% of flights started between 0 and 120 metres high.

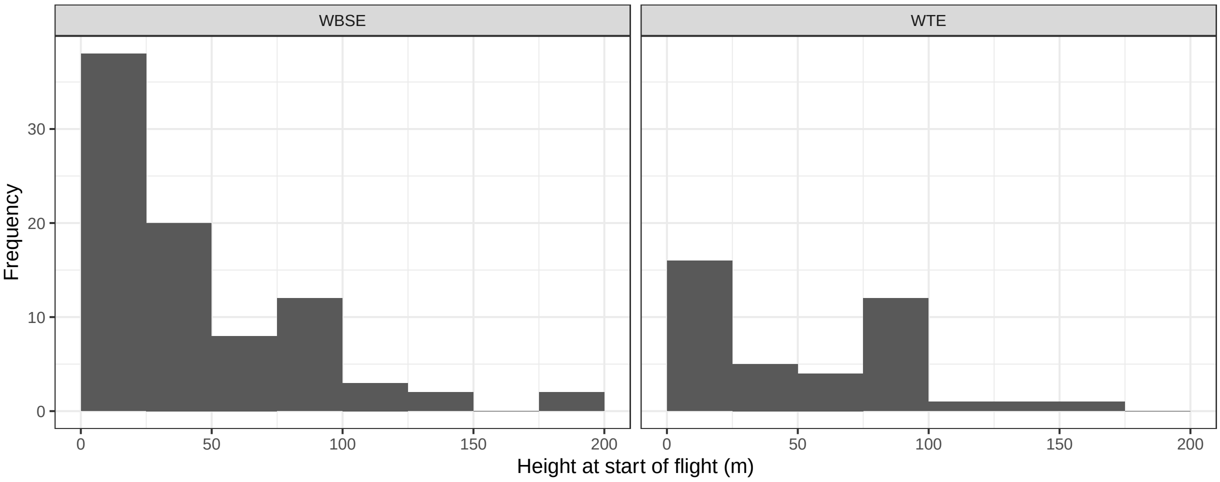

Figure 5: Distribution of flight heights by species.

The survey has produced flight data across all times of day, and sampled a selection of flight heights and locations.

3 Estimate of total eagle flight density

This section aims to understand the eagle activity over the site.

3.1 Methods - distance corrections

To provide a robust estimate of the rate of flight activity onsite, one must adequately account for the possibility that an observer will be more likely to detect a flight that is overhead, than one that is a large distance away. This was done using standard distance correction techniques (Buckland et al. (2008)). It requires GIS analysis, and so is only performed on flight tracks with full GIS associated data.

We used a half-normal distribution to model the detection function. Other shapes (uniform with a cosine series expansion, and hazard-rate) models were also explored. However, the half-normal was chosen for its simplicity (as there weren't a great number of data points), and its alignment with the shape of the data. We used the Akaike Information Criterion (AIC) (Akaike 1974) to compare models. There was no evidence (using AIC) of a statistically significant difference between the detection rates of WBSEs and TWTEs.

Here, "distance" was defined as the straight line distance between the observation point, and the first recorded eagle flight point, ignoring height. We truncated the data at 2045 metres (the 90th percentile of the distance data) as to remove the effects of outliers. Truncating at the 90th percentile for point transects is recommended by Buckland et al. (2008) (p151). We believe this is a sensible value, as not truncating results in a detection function which fits poorly (the curve fits to the long tail, rather than the main body). This is supported by the survey methodology document (Nature Advisory, n.d.), which states that it's unrealistic that flights are observed at greater than roughly 2 km from the survey point - meaning that the distances greater are potentially outlier values.

From the distance models, we obtain the *effective detection range* (EDR), which provides a measure of the detectability in the study area. Larger EDRs suggest that detection is good at large distances, and the activity rate requires a smaller correction for undetected flights. The philosophy behind the EDR is, given that the detection efficiency decreases as we increase the distance, we can equivalently re-state the detectability as "100% of flights are observed within the EDR". Larger EDRs suggest that detection is good at large distances, and the activity rate requires a smaller correction for undetected flights.

The EDR collapses an extended curve, which has decreasing detection with greater distance, into a confined area with 100% detectability. Given this area and the observed flights, we can then project flights over the whole site, to assess eagle activity rates.

To obtain a measure of uncertainty on the EDR, we use the bootstrap (Buckland et al. 2008). The bootstrap is a stochastic technique involving resampling of the dataset in order to obtain "replicate" sets. The variation in replicate sets can be used to estimate the population variance.

3.2 Results

Figure 6 summarises the distance at which flights were first detected (regardless of species), and a theoretical fit from a half-normal distribution. We note the unusual discrepancy between the number of observed flights which were first seen close the the observer, which is a lot more than the theoretical fit. This is surprising because there is more area in which to see an eagle the further one is from an observer, so we expect an increase in the curve before a decrease (the area "conflicts" with the decreasing detectability as distance increases).

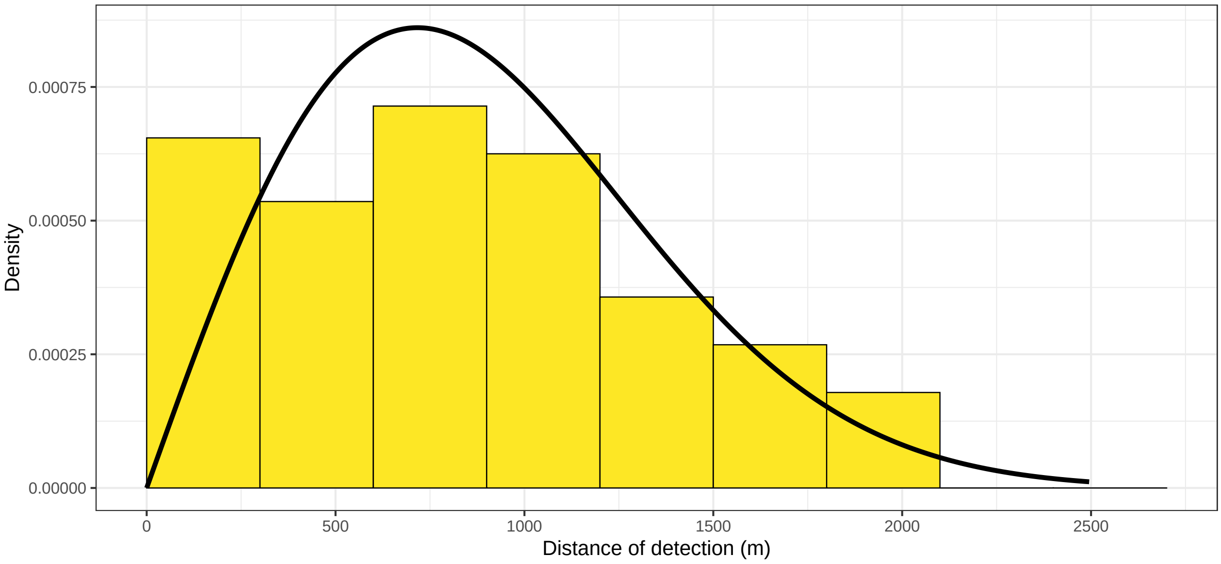

Figure 6: Histogram of (truncated) observed distances of detection, overlaid with the fitted curve for detection distance.

The effective detection range for eagles is 1005 metres with a 95% confidence interval of (872, 1131) metres.

Table 5 provides distance-corrected activity rates for the site. We define the site as a 1 km boundary around Robbins Island landmass (this is the site boundary in the maps throughout this report). The total site area is taken to be 16173.91 hectares, as defined by the provided spatial object[1].

Table 5: Raw counts of observed flights, and distance-corrected activity rates with corresponding 95% confidence intervals.

Species	Flights observed	Flights/hr/ha	Flights/hr (site)
WBSE	85	0.0012 (0.00093, 0.0016)	19 (15, 25.2)
WTE	40	0.00055 (0.00044, 0.00073)	8.9 (7, 11.9)

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[1] `Robbins_Island_1km.shp`

4 Spatial mapping

Flight tracks were recorded by Nature Advisory and provided as GIS set. The tracks were then “smoothed” over the surrounding area using kernel functions, which then provides a 2D probability map over the study area.

4.1 Methods - kernel smoothing

To understand the relative spatial patterns in flight density we need to transform the individual flight tracks into a smoothed probability map for the whole area. The flight points are “smoothed” using a kernel function (Figure 7 illustrates the concept with a simpler 1-dimensional method)[2]. For an introduction to kernel methods in ecology see Worton (1989) or Fulk and Quinn (1996) for more detailed mathematics.

The resulting maps are a visualisation of the likelihood that a flight will be seen at a particular location, relative to the other locations. That is, it answers the question: “if a flight exists in this area, where is it likely to be?”

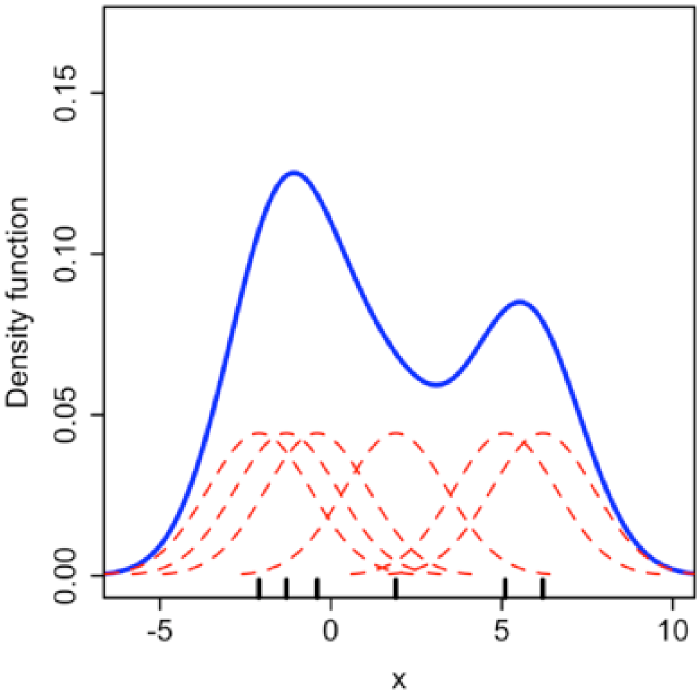

Figure 7: Schematic of kernel methods. The contributions of individuals points (small vertical lines along the x axis) are smoothed using a kernel (red dashes curves). The overall density is the combination of all the kernels at a given point (blue curve).

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[2] “Comparison of 1D histogram and KDE”. Created by Drleft and edited by A. Jackson (Symbolix). Available under the Creative Commons Attribution-Share Alike 3.0 Unported license.

We used a W4 kernel function with smoothing parameter $h = 1500$ metres. This kernel function has a Gaussian-like shape, but compact support - a single point on a flight path is smoothed to no more than $2 \times h$ metres away from the original point. While the smoothing, to some degree, provides a safety buffer to account for the difficulty of recording exact flight tracks, mostly we smooth to account for natural flight variability, to answer: "even though an eagle flew here today, if it flew again, where is it likely to be?"

Prior to smoothing, we re-spaced the points on the flight path to a consistent distance (four metres). The raw flight paths had point spacing from anywhere between 10 and 1715 metres, which meant that if we smoothed on the raw data, some flight paths would erroneously contribute more weight to the spatial map than others. Once re-spaced, the contribution of each flight to the spatial map was proportional to its length.

4.2 Results

Figures 8 and 9 plot the contours of utilisation for WBSEs and TWTEs respectively. The green and yellow contours have the higher levels of utilisation, and the utilisation level decreases as the colour tends towards blue and purple.

These plots also show (in pale grey) the raw flight tracks, so we can see how they contribute to the final spatial maps.

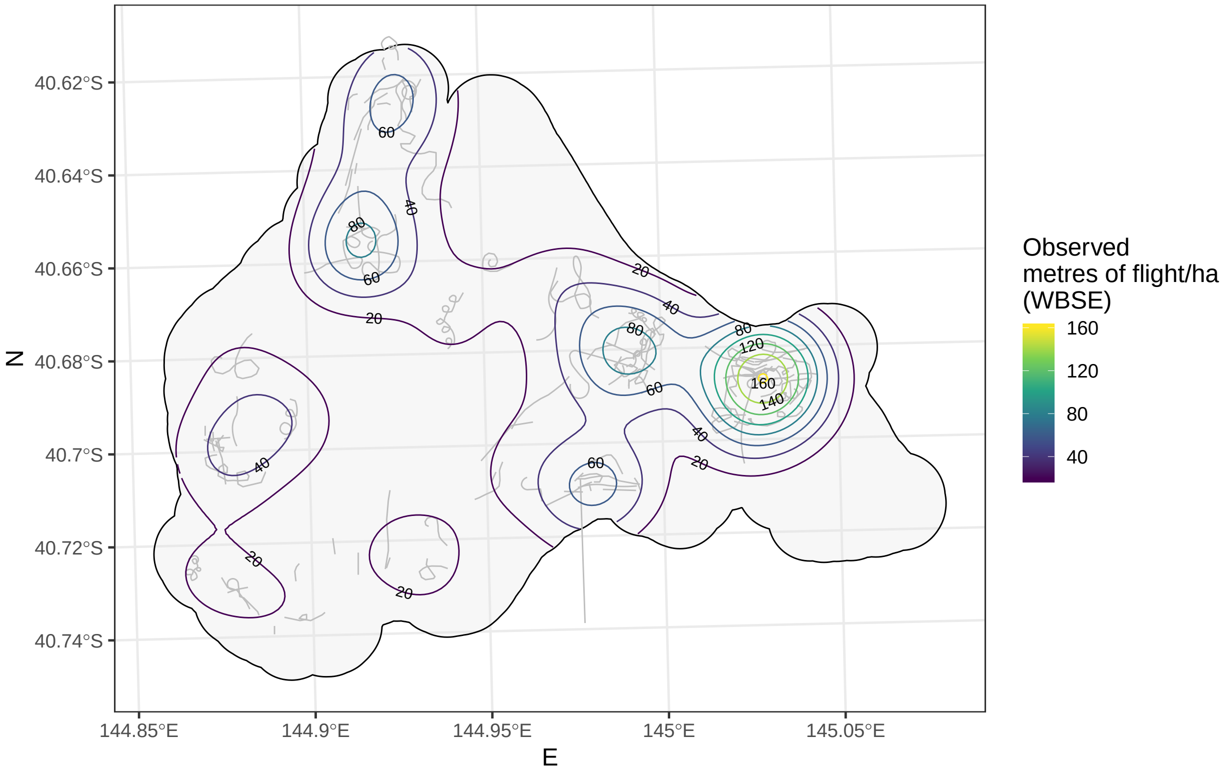

Figure 8: Contour map of WBSE utilisation, overlaid on study area (boundary line) and with raw flight traces in grey. This combines the spatial mapping / kernel smoothing with the observed metres of WBSE flights over the whole farm.

In Figure 8, we can see that WBSEs utilise most of the island, with a stronger tendency to fly in the central-east and north.

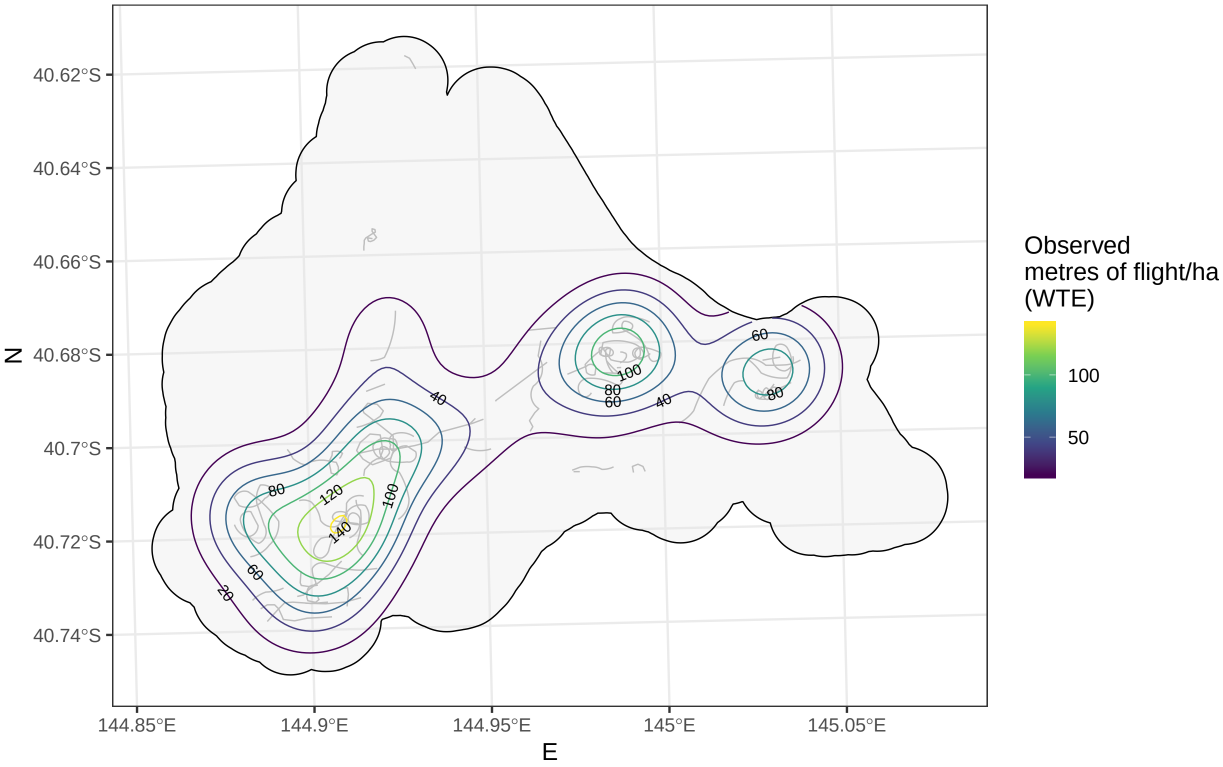

Figure 9: Contour map of TWTE utilisation, overlaid on study area (boundary line) and with raw flight traces in grey. This combines the spatial mapping / kernel smoothing with the observed metres of TWTE flights over the whole farm.

In Figure 9, we can see that TWTEs were observed more in the central and south-west areas.

We have not attempted to look for patterns at any level deeper than species. This is because there is not a lot of flight path data.

While there are areas in which we have observed more eagle flights, overall the spatial distribution looks quite uniform throughout the study area.

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