Statistical Draft Report for Wind Relic & Arcus

Rippon

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This report has been prepared for Wind Relic and Arcus Consulting who requested a statistical analysis of the bat acoustic data for the Rippon development footprint. This report is based on the report provided to Wind Relic in September 2020 but using only a subset of monitoring sites which are in or near the Rippon development footprint. The following sites were included in the analysis: C4, C19, C20, C21 and C22. One site (C4) is a short mast, while the others are meteorological masts. All predictions using height were done up to 150m, these predictions need to be interpreted with caution since recordings were only made at 12m, 50m and 80m so these predictions are well beyond the range of the observed data.

The dataset contained 332 446 records, with a total of 80 921 bat passes. Eleven bat species were recorded at these sites. The associated climatic data were only not available for one of the monitoring sites (C4).

Summary of Available Data

Table 1 provides a summary of the total number of bat passes and average bat passes per night. The average number of bat passes per night at the lower level (12m) recording site is substantially higher compared to any of the meteorological masts which recorded at 50m and

80m (Figure 1). Sites C19, C21 and C22 showed slightly more activity at the higher height, while site C20 showed lower activity levels at 80m compared to 50m (Table 2).

Table 1 - Summary statistics of recording sites

Site	Heights	Total Bat passes	Number of Nights	Average bat passes per night
C4	12m	47 398	433	109.46
C19	50m and 80m	3 510	199	8.84
C20	50m and 80m	6 531	261	12.51
C21	50m and 80m	14 296	357	20.05
C22	50m and 80m	9 186	271	16.95

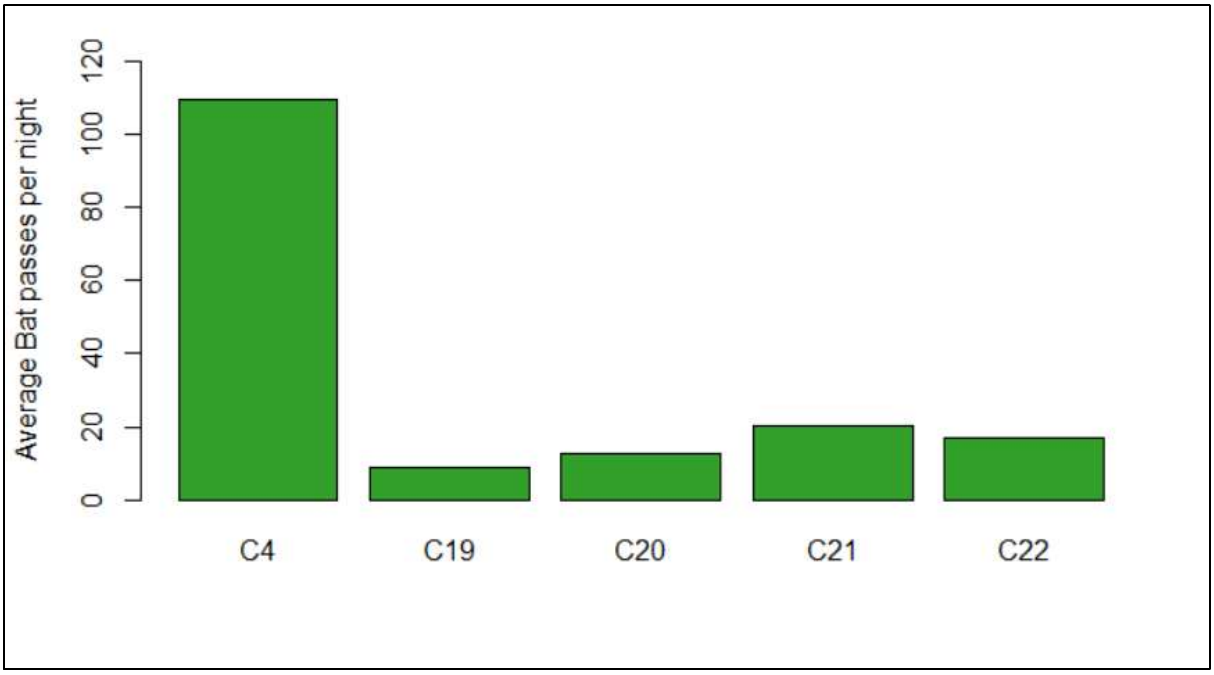

Figure 1 - Average number of bat passes per night plotted by site

Table 2 - Summary of recording sites split by height

Site	Height	Total Bat passes	Average bat passes per night
C19	50m	1570	7.89
	80m	1940	9.80
C20	50m	4842	18.55
	80m	1689	6.47
C21	50m	6788	19.01

	80m	7508	21.09
C22	50m	3959	14.61
	80m	5227	19.29

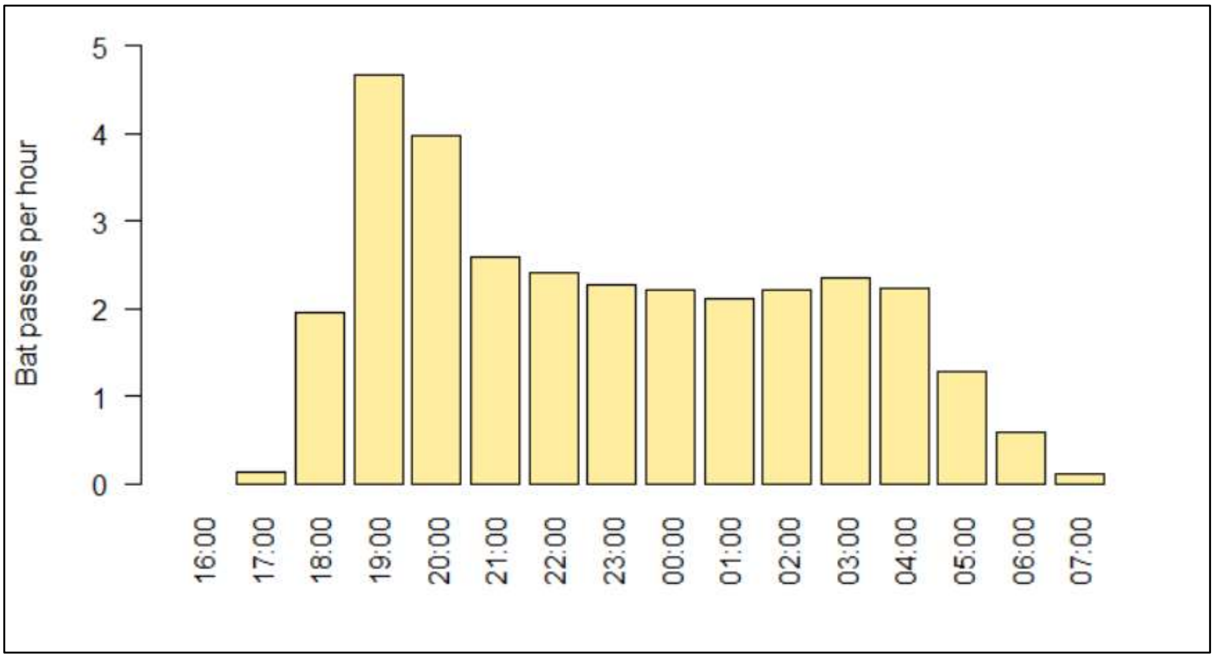

Figure 2 - Average number of bat passes per hour by time of day

The bat activity showed a peak around dusk and early night (19:00 and 20:00) and declined slowly through the night until 04:00 after which there was a substantial decrease in activity, see Figure 2. The hourly patterns of activity in summer and spring are similar with a spike at 19:00 in spring and 20:00 in summer followed by much lower activity thereafter. Winter and autumn show more consistent activity throughout the night after the early evening peak (see Figure 3).

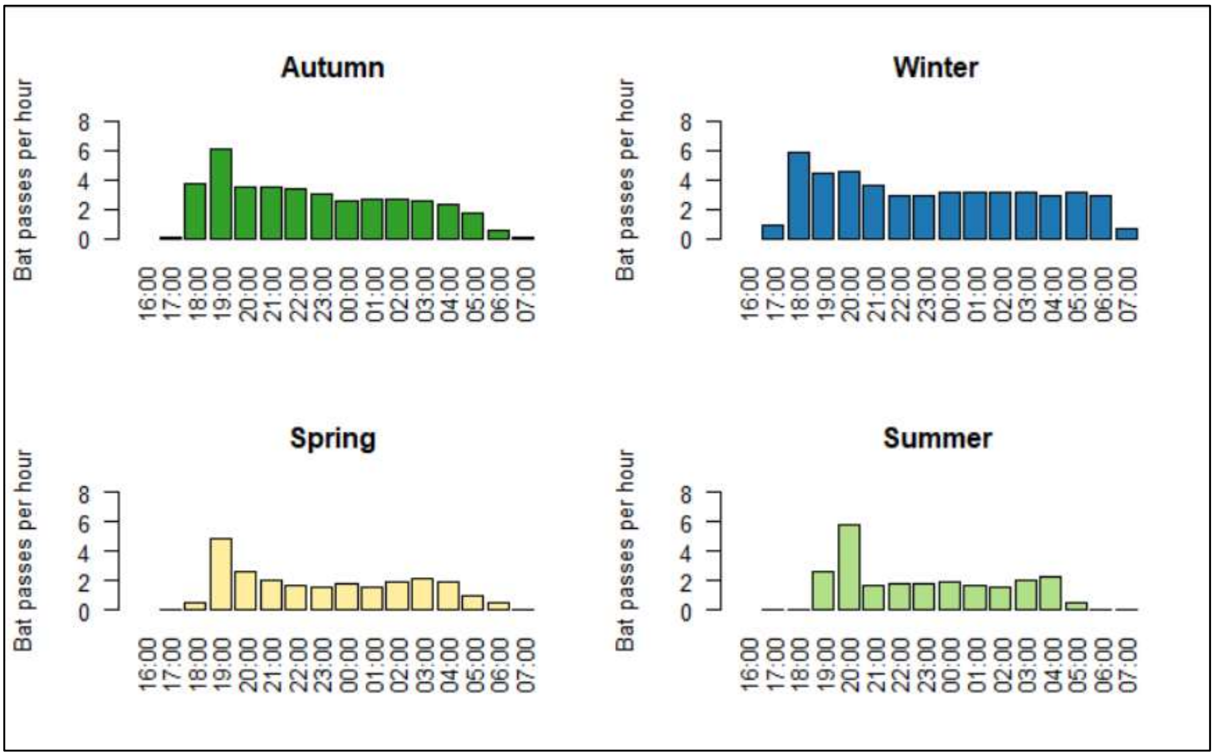

Figure 3 - Seasonal split showing average number of bat passes per hour by time of day

Vertical Activity Profiles

To build bat activity profiles, I first used the number of bat passes per hour at each height considering all recorded species pooled. At ground level, site C4 showed very high activity levels. This site is located approximately 8km north of the Rippon development. C20 and C22 which fall within the Rippon footprint show lower activity levels (see Figure 4).

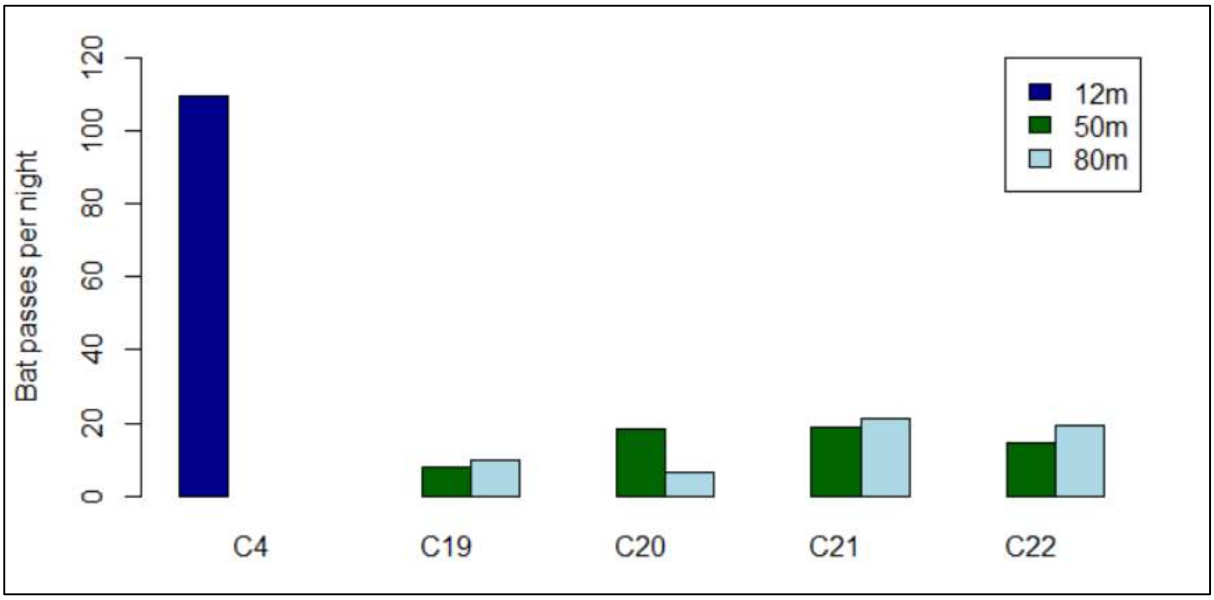

Figure 4 - Average number of bat passes per night plotted by site and height

The vertical activity for all sites pooled shows that the majority of activity occurred at lower levels (below 50m) which is being driven by the very high activity at the only low-level recording site (C4), see Figure 5, with similar levels of activity at 50m and 80m.

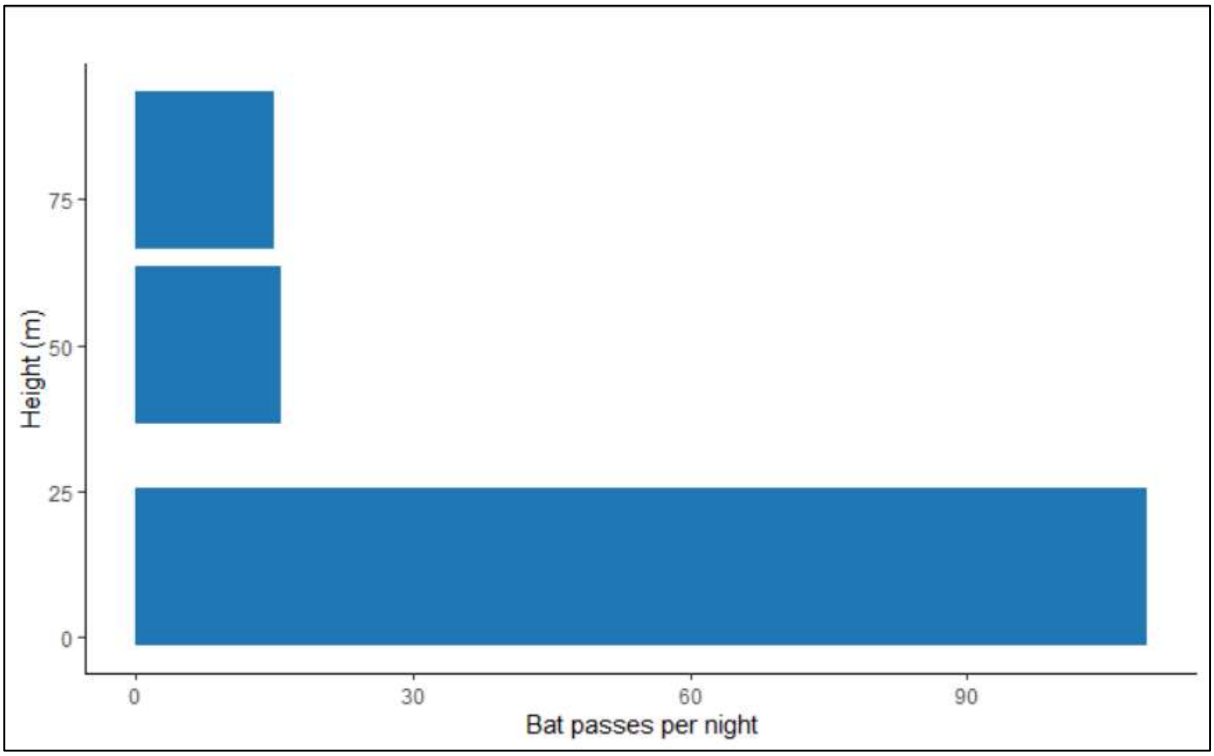

Figure 5 - Observed vertical bat activity profile

To model vertical activity profiles up to 150m above ground level, I used a linear model describing the mean number of bat passes per recording night as a function of the natural logarithm of height. The model found no significant linear relationship between the natural logarithm of height and the mean number of bat passes per night ($t = -4.201, p = 0.149$).

Similar models were then run for the two species, split by season and modelling the mean number of bat passes per hour as a function of the logarithm of height. The results are shown in Figure 6. For the Egyptian free-tailed bat the predicted number of passes per hour decreases exponentially with increasing height, except in autumn which shows increased number of passes at higher levels. The Little free-tailed bat shows increased predicted number of passes with increasing height in autumn and spring, with very little change in predicted activity with changing height in summer. In winter, the Little free-tailed bat shows an exponentially decrease in activity with increasing height. However, none of the seasonal models showed significant relationships between height and the mean number of bat passes.

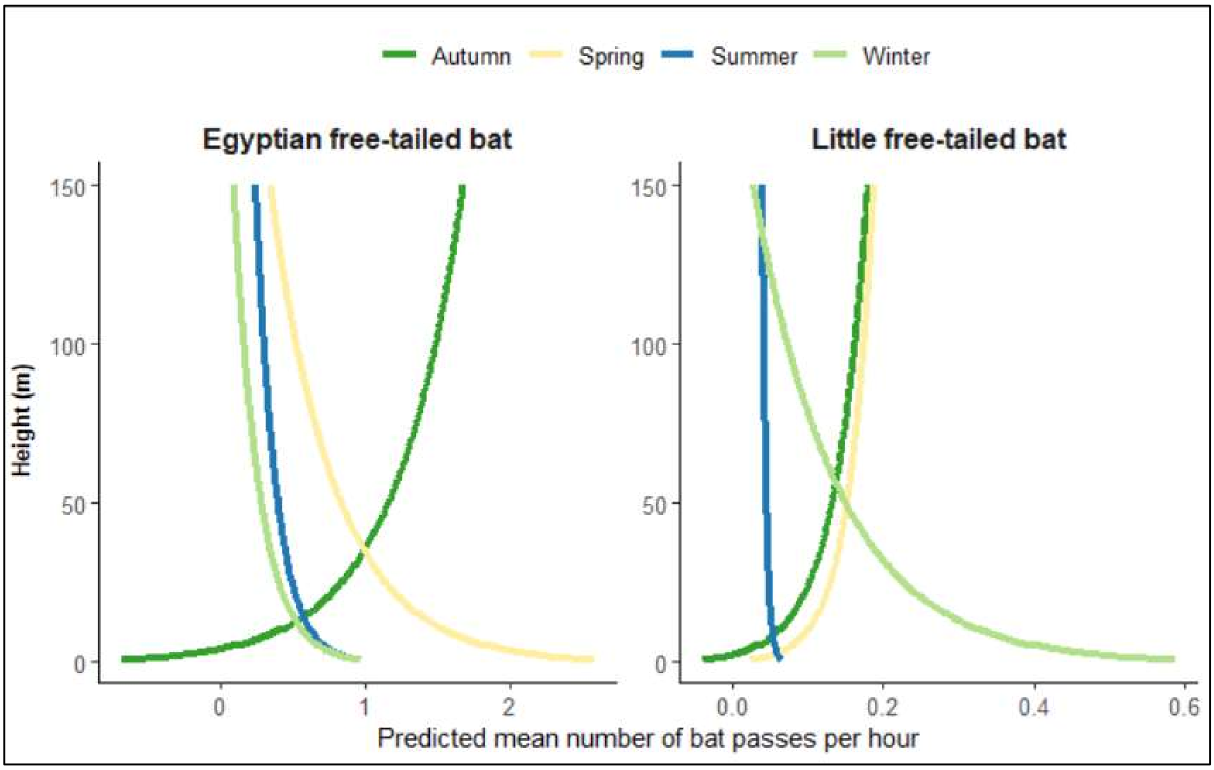

Figure 6 - Predicted mean number of bat passes per hour with height

Effect of wind speed on bat activity

In order to investigate the relationship between bat activity and wind speed, I calculated a *probability of activity occurrence per hour (p)* using a logistic regression. For this, I transformed the raw activity data (number of bat passes per hour) into simple presence/absence (binomial distribution) per hour. The probability of activity occurrence per hour was modelled as a logistic regression using average wind speed or maximum wind speed as the predictor variable. However, at the meteorological sites wind speed data were only recorded at sites C19, C20 and C22. In autumn only site C20 had wind speed data recorded and during the recording period no bat passes were recorded. In spring site C19 and C22 recorded wind speed data and in summer and winter only site C19 had associated wind data.

The results of the logistic regression showed that neither the average nor the maximum wind speed were significant predictors of the probability of bat occurrence. The fit of the full and the null (excluding the predictor variable) was compared using a likelihood ratio test statistic. The results are given in Table 3.

Table 3 - Results of logistic regression models of probability of bat occurrence against wind speed

Height	Variable	Test Statistic	Degrees of Freedom	*p*-value
50m	Average wind speed	2.769	1	0.096
50	Maximum wind speed	2.539	1	0.111
80	Average wind speed	0.097	1	0.755
80	Maximum wind speed	0.199	1	0.655

Plots of the fitted models are shown in Figure 7. This pattern is very different compared to other development footprints in the region (see previous reports), showing an increase in predicted activity with increasing wind speed. However, given the limited wind speed data and lack of significance of the relationship, this pattern is unlikely to be true reflection of the relationship between wind speed and bat presence in this development footprint. Due to the lack of relationship between presence and wind speed and limited data, no additional seasonal or monthly models were fitted.

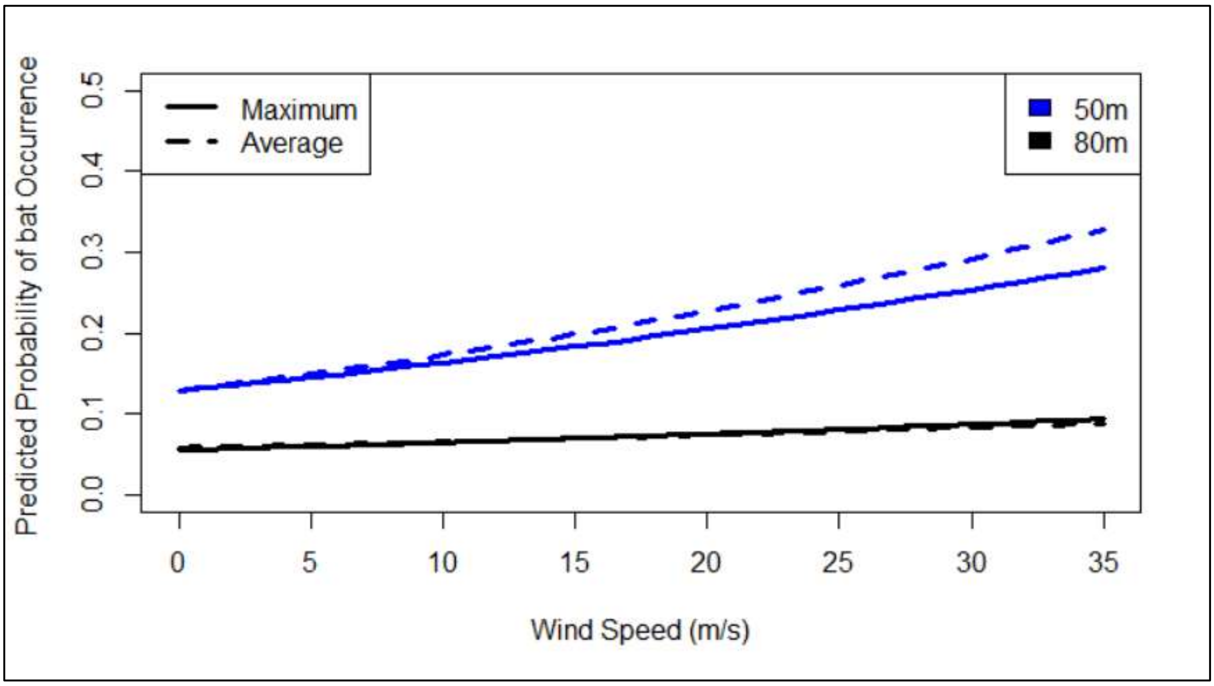

Figure 7 - Predicted probability of bat occurrence from logistic regression models

Effect of height on bat presence

I then used the data from all sites to model the probability of bat presence using a logistic regression model, with site as a random effect. The results of the model of height and month are shown Figure 8. The predicted probability of a bat being present decreases at 1% per unit increase in height. The probability of a bat being present is predicted to be highest in April with June having the lowest probability of presence.

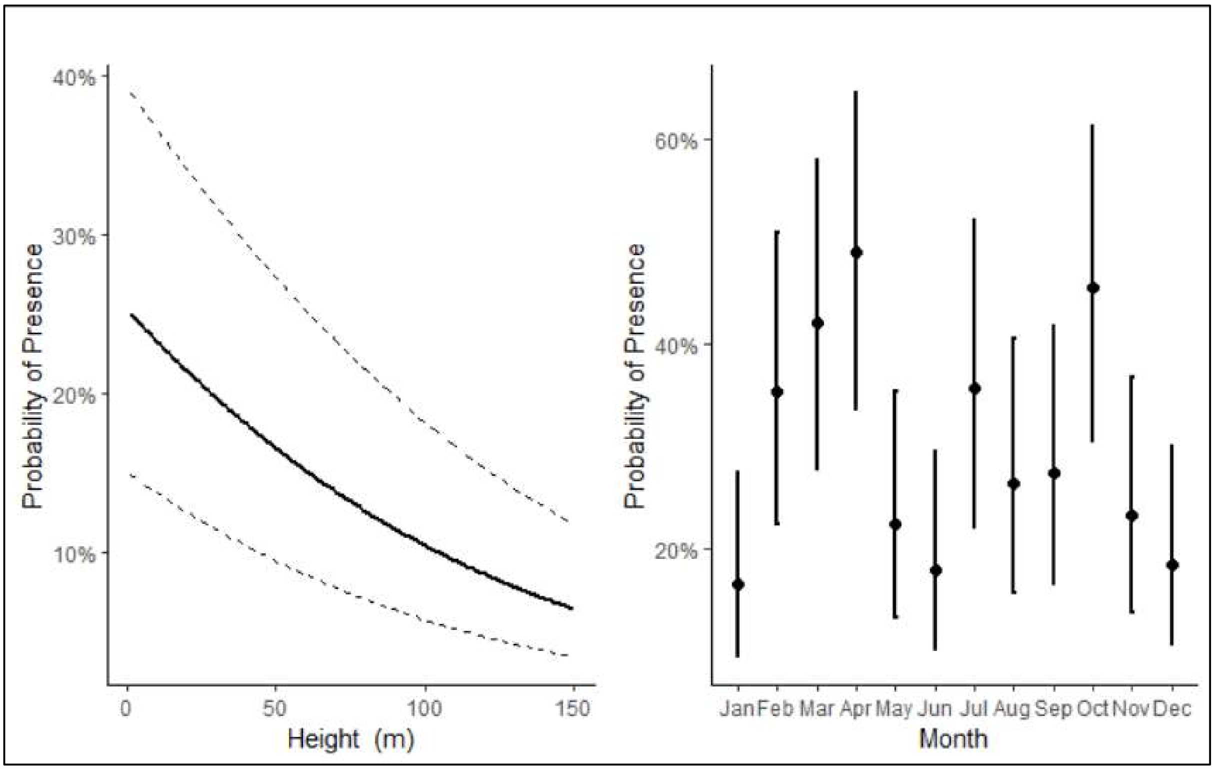

Figure 8 - Logistic regression using all sites (random effect) with height and month

A model of presence/absence against height and time of day also showed the pattern of decreasing probability of bat presence with increasing height. The plot for time of day is shown in Figure 9. The predicted probability of bat presence peaks at 20:00 and declines consistently through the night.

Figure 10 shows the relationship between the predicted probability of a bat presence and height for two species at the two meteorological recording sites. These plots show an increasing probability of a presence at increasing height at all sites except C20.

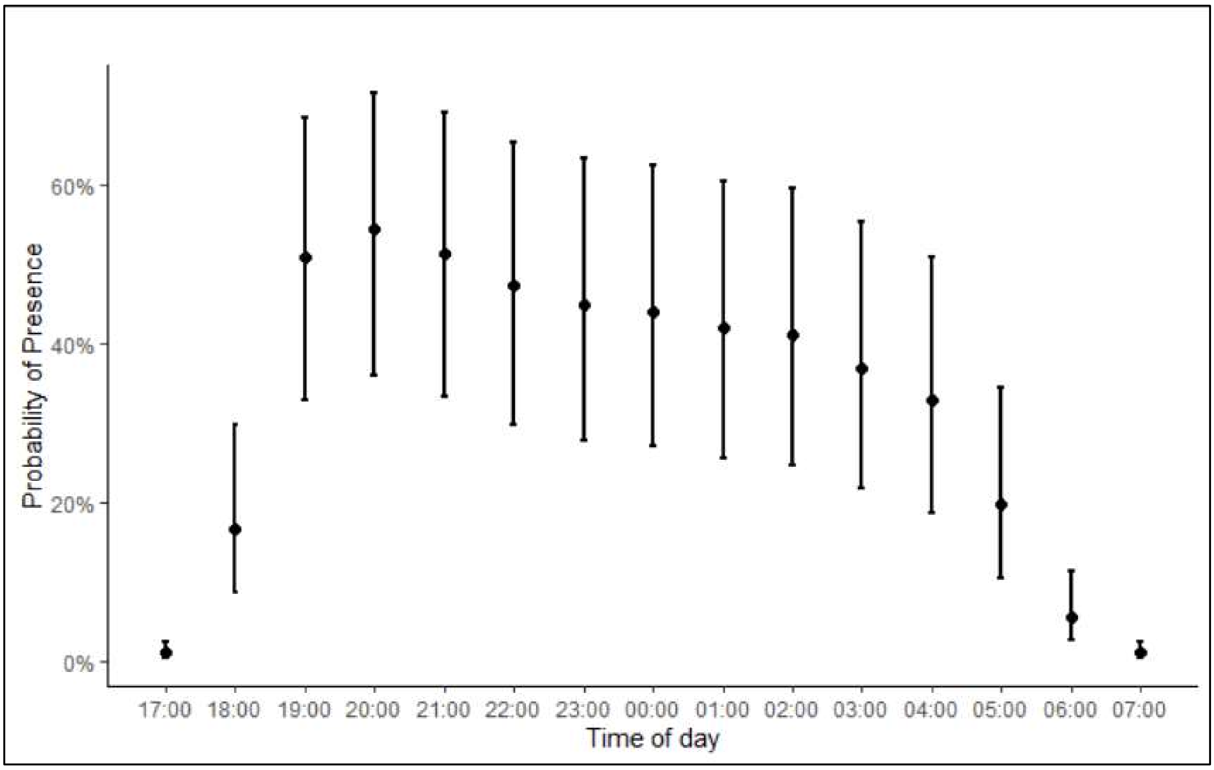

Figure 9 - Logistic regression using all sites (random effect) with height and time of day

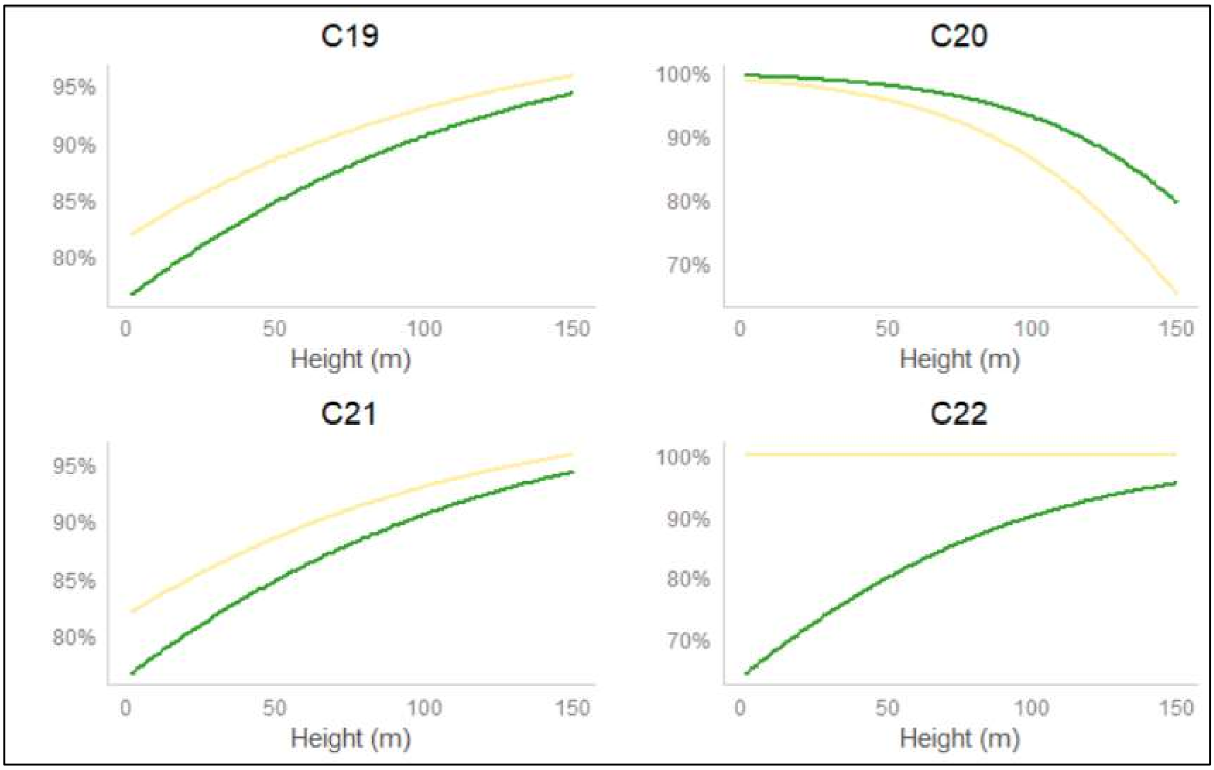

Figure 10 - Probability of presence of Egyptian (yellow) and Little (green) free-tailed bats with height