Bats with Altitude: Determining the presence of bats in high altitude locations within the British Lake District

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Abstract

Static detectors were used in locations across the Lake District National Park, Cumbria to record bat activity at locations generally above 500m elevation (approximate treeline). Bat activity was detected at over half of all sites surveyed, albeit at relatively low levels (average 6.3 passes per night) and in all months surveyed (April-October 2016 and May-August 2017).

All eight species known to be resident within the county were detected using habitats above 500m; the most common species was common pipistrelle *Pipistrellus pipistrellus*. A low number of bats were detected close to sunset, suggesting summer roosting behaviour at altitude. However, the majority of recordings were notably later, suggesting that bats were commuting to the sites from lower elevations. There were no significant correlations between bat activity and habitat features.

Background

UK bats are some of the best studied in the world; nationwide surveys under the National Bat Monitoring Programme have been carried out since 1996 (Bat Conservation Trust, 2020). Yet, although hibernation behaviour has been studied at some moderate elevations (for example Easegill caves at approximately 300m), little appears to be known about summer bat activity in the higher elevation habitats of the British Isles, areas such as the

Lake and Peak Districts of England, Snowdonia and the Brecon Beacons of Wales and the Highlands of Scotland.

Internationally, studies have been undertaken investigating the altitudes of flying bats; these have demonstrated that many species are present at comparatively high altitudes. Mexican free-tailed bats *Tadarida brasiliensis* can be found at up to 1,118m above sea level (McCracken *et al.*, 2008), while migrating bats, such as the North American hoary bat *Lasiurus cinereus*, have been documented at up to 3,000m (Peurach, 2003). In Zimbabwe at least six *Molossidae* and one *Emballonuridae* bat species were found feeding at 600m above the ground (Fenton *et al*., 1997).

Although occasional anecdotal reports of bats observed within mountainous habitat exist, there is little published research on bats foraging above the treeline in high-altitude terrain in the UK (Google Scholar search using keywords: '*bats altitude*', '*bats altitude UK*', '*bats altitudinal gradient*', '*bats elevation*'). One of the few studies we could find was undertaken by Dunn and Waters in 2003, which monitored common and soprano pipistrelle *Pipistrellus pygmaeus* activity across an altitudinal gradient on the Isle of Man; this study sampled activity up to 400m above sea level.

It is generally accepted that Chiroptera, as an order, favours warm habitats; the greatest density of bat species being found within the tropics (Altringham, 1996). Higher altitude habitats, where temperatures are comparatively low, are therefore likely to be less favourable for bats. A comparative study by Erikson and Adams (2003) looking at bat use of high and low elevations in Washington, USA, showed that activity levels were four times greater at low elevations (<150m) than at high elevations (>575m).

Although Britain does not boast any of the highest mountains of Europe, the conditions that can be experienced at the summits of this countries comparatively minor peaks can be disproportionately harsh. Bats seeking to forage within this inclement environment are likely to experience frequent fluctuations in temperatures, strong winds and heavy rain, all within an open and barren habitat with few available roosting locations. In the UK, the treeline is at about 500-600m. Therefore, the above study (Erickson and Adams, 2003), and similar studies, such as those undertaken in British Columbia by Grindal *et al*. (1999) cannot be used as a model because, unlike UK mountains, the habitat surveyed was forested throughout and therefore provided a more suitable location for roosting and foraging bats.

Whilst undertaking a bat habitat modelling study across the southern Lake District in 2013, Chloe Bellamy, of Leeds University, recorded occasional commuting bats above the fells (exact elevation unknown). While, in advance of our study, occasional informal visits were made by the author to relatively high-altitude locations (550m) to determine if bats could be encountered; bats were recorded on all visits.

Aim

It was therefore decided to embark on a study to attempt to establish the following:

- Whether bats use high altitude locations (above 500m)
- Which bat species are encountered on high ground

- Do habitat features have a significant impact on the presence of bats within these locations

Method

Site Selection

The Lake District National Park, in Cumbria, was chosen as a survey area. Cumbria hosts eight resident and two vagrant bat species (for which there are currently no county roost records for (Cumbria Biodiversity Data Centre, 2021)).

Table 1: Cumbrian bat species.

Resident	**Vagrant**
Daubenton's bat *Myotis daubentonii* Brandt's bat *Myotis brandti* whiskered bat *Myotis mystacinus* Natterer's bat *Myotis nattereri* noctule *Nyctalus noctula* common pipistrelle *Pipistrellus pipistrellus* soprano pipistrelle *Pipistrellus pygmaeus* brown long-eared bat *Plecotus auritus*	Leisler's bat *Nyctalus leisleri* Nathusius' pipistrelle *Pipistrellus nathusii*

The national park was divided into 3km quadrats (Figure 1). Those that contained land above 500m were numbered from 1 to 80. The aim was to carry out a period of static bat detection within as many of these quadrats as possible.

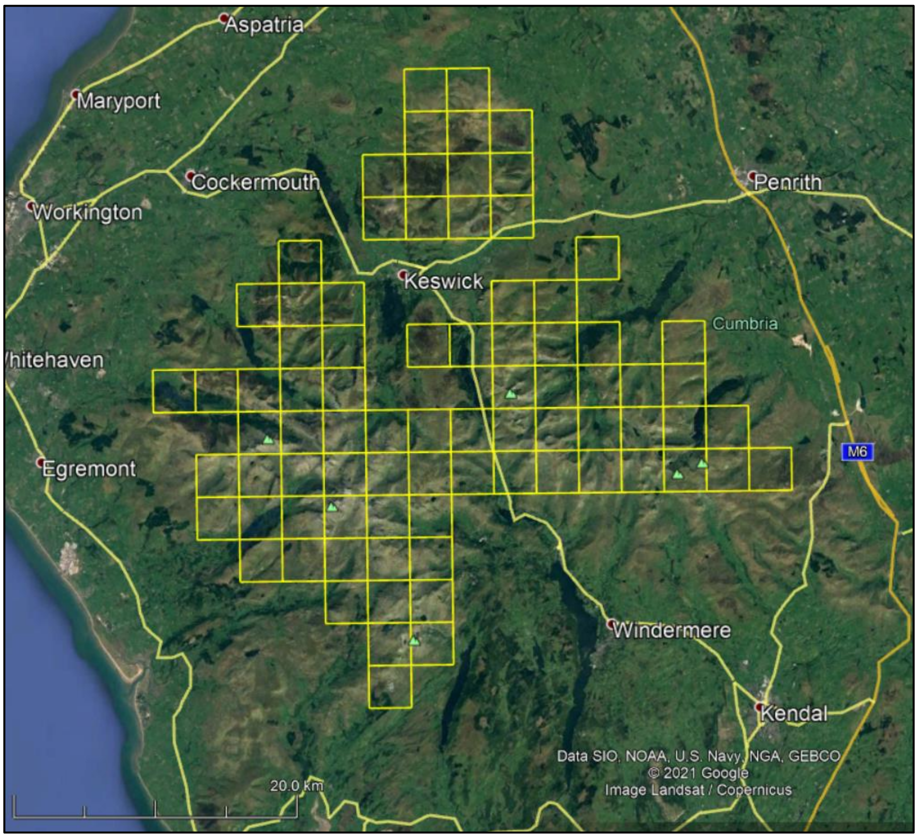


Figure 1: Survey quadrats.

Survey Period
Data was collected between April and October 2016 and between May and August 2017. As activity was expected to be low, it was decided to focus on the months where activity was expected to be highest.

Data Collection
Thanks to funding from the South Cumbria Bat Group (SCBG) and a grant from the Lake District National Park Authority (LDNPA), Anabat Express detectors were procured, bringing the number of available SCBG owned Anabat Expresses up to seven.

The majority of the survey locations were in remote mountainous situations, only accessible on foot. A request was put out on social media and through the bat group and Cumbria Wildlife Trust for volunteers who would be willing and capable of walking to these locations to deploy the detectors. A team of twenty volunteers was established, many of whom had no experience with bat surveying. Volunteers were given an introduction into the operation of the static detectors; the Anabat Express was chosen in particular, due to its ease of use for the inexperienced surveyor.

An online rota was established where volunteers could sign out detectors and see which quadrat squares needed to be surveyed. Volunteers would choose a location within the 3km quadrat that was above 500m elevation. As the detectors are designed to be deployed unmanned, volunteers were required to hide them so that they would not be found by passers-by. Due to the barren nature of the landscape, this would frequently require hiding the detectors beneath piles of rocks or under moss piles (Figures 2 and 3). The Anabat Express is protected by a waterproof housing and can therefore withstand getting wet, as long as the microphone does not get soaked.


Figures 2 and 3: Anabat deployment locations. © Richard McGuiness and Jane Newport.

The Anabat Express units were programmed to 'Night Only' mode, which activates 30 minutes before sunset and turns off 30 minutes after sunrise. This program mode was selected for its ease of operation, the lower demand on batteries (compared to 'Continuous' mode) and the fact that day-flying bats were considered to be relatively unlikely.

Fresh batteries lasted for a maximum period of 20 days, therefore, in general detectors were left *in situ* for at least two weeks in the period between April and October 2016. In

2017, nine additional quadrats were sampled, but the intensity of effort was markedly reduced; all being surveyed by a single volunteer.

Habitat data was collected for each of the sample locations, through the use of aerial imagery and GIS mapping. Distances were measured to landscape features that may have some influence on bat activity:

- Becks (streams)
- Crags or Rocky Outcrops
- Marshy Ground
- Footpaths
- Tarns (standing water)
- Trees
- Buildings

Data Analysis

Anabat Express detectors record to SD cards in ZC file format. Volunteers were required to download the files and email them to the project co-ordinator for analysis. Analysis was undertaken using AnalookW. Calls were identified to species level, where possible, including *Myotis* bats. However, where definitive species identification could not be established (due to the well-known acoustic overlap between species) *Myotis* sp. files were identified to genus level only. ''Big bats' (*Nyctalus* and *Eptesicus* species) and *Plecotus* sp. bats were all identified to species level due to the presence of only one resident species of each group (e.g. noctule and brown long-eared bat) in Cumbria.

Simple one-tailed Analysis of Variance (ANOVA) tests were run, using Excel, to determine whether the mean nightly bat passes had any significant dependence on the various habitat proximity values.

In addition, Regression Analysis was undertaken to establish if a significant correlation existed between the mean nightly bat passes and the minimum daily temperature or daily rainfall amounts.

Results

Of the 80 possible quadrats, 38 were surveyed in 2016 and a further nine were surveyed in 2017. In total, 179 individual nights were surveyed in 2016, however, with multiple detectors deployed on the same nights, the total number of survey nights in 2016 was 513 (Figure 4). In 2017, 91 individual nights were surveyed, with a total of 131 survey nights undertaken.

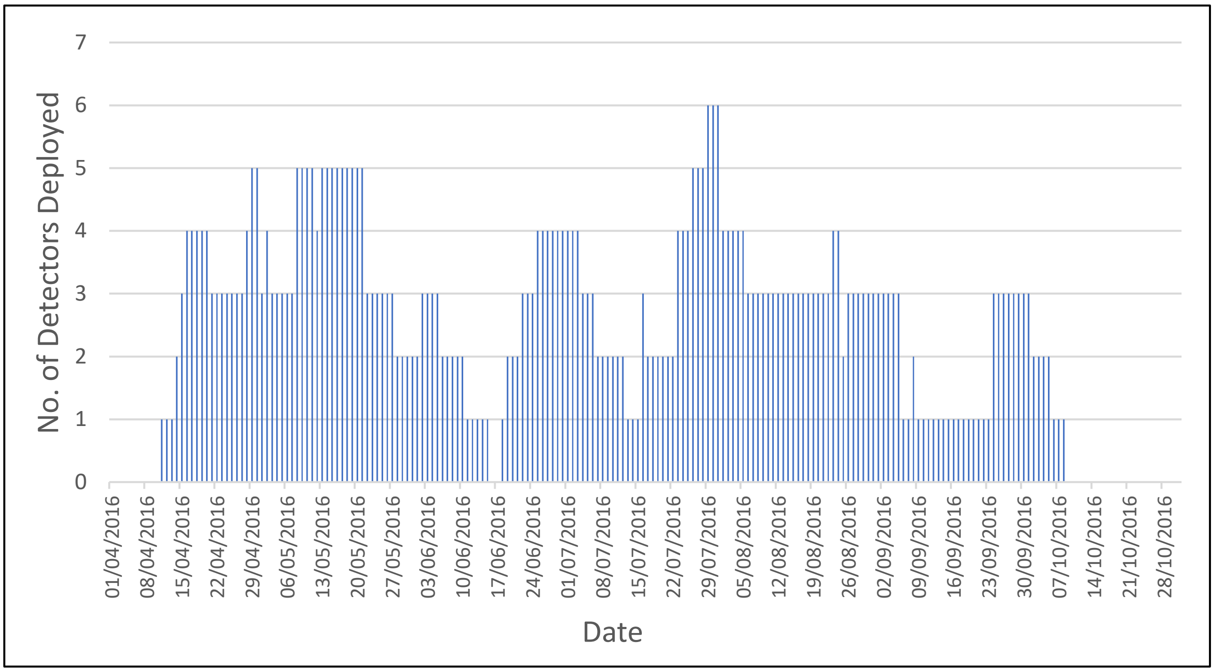


Figure 4: Survey nights in 2016.

The minimum period of deployment was eight consecutive nights and the maximum was 20 (although one detector ran out of battery power after a single night); the average deployment period was 13 nights. Due to the variation in deployment periods, a mean number of bat calls per night was obtained for each location, which could provide a comparative value.

Of the 47 locations surveyed during 2016 and 2017, 27 sites recorded bats. In total 3729 files were identified that contained bat calls. Some files contained multiple species, therefore a total of 4040 individual bat passes was recorded.

Of the eight resident Cumbrian species, all eight were identified (Figure 5), although not always to species level. The dominant species was common pipistrelle with 2593 passes, over five times more than the next most prevalent specie group, which was *Myotis* (479) followed by soprano pipistrelle (438). The dominance of common pipistrelle is demonstrated by the fact that it features in 64% of the bat files recorded. Naturally, it was also recorded on the highest number of nights (Table 2). The least numerous species of bat to be encountered were whiskered bat (5) and Brandt's bat (22). However, it can be assumed that a proportion of the *Myotis* species files should be attributed to these species. The most common *Myotis* bat was Daubenton's bat; conversely to whiskered and Brandt's bat identification, this may be because this species of bat can be more readily identified through sound analysis than other *Myotis* species.

Noctule and brown long-eared bat both featured a similar number of times, with just 86 and 85 files respectively; they were also recorded on a similar number of nights (34 and 38), giving them similar mean number of passes per detected night. All *Nyctalus* calls were examined for the possibility of Leisler's bat; however, no files matched the parameter profile of Leisler's bat.

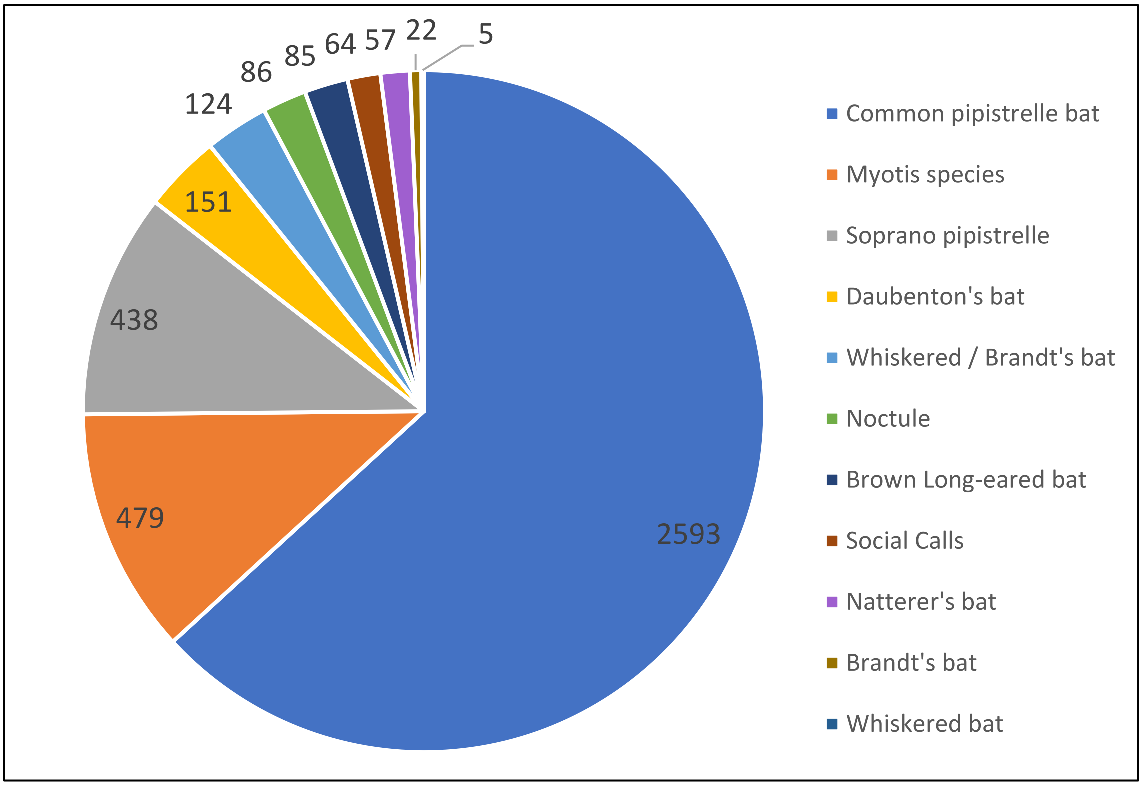


Figure 5: Proportion of recordings by call type.

Table 2: Number of bat calls and nights recorded, by species.

Species	**Total Calls Recorded**	**No. Nights Recorded**	**Mean No. of Calls Per Recorded Night**
Common pipistrelle	2593	80	32.4
Myotis species	479	52	9.2
Soprano pipistrelle	438	55	8.0
Daubenton's bat	151	26	5.8
Whiskered/Brandt's bat	124	18	6.9
Noctule	86	34	2.5
Brown long-eared bat	85	38	2.2
Social Calls	64	23	2.8
Natterer's bat	57	24	2.4
Brandt's bat	22	3	7.3
Whiskered bat	5	3	1.7

64 files were found to contain social calls; these were predominately pipistrelle type D social calls (Figure 6). Over half of the files (36) were recorded within the period 22/08/16 to 03/09/16 when mating and therefore mate attraction and competitor antagonism is likely to be strong.

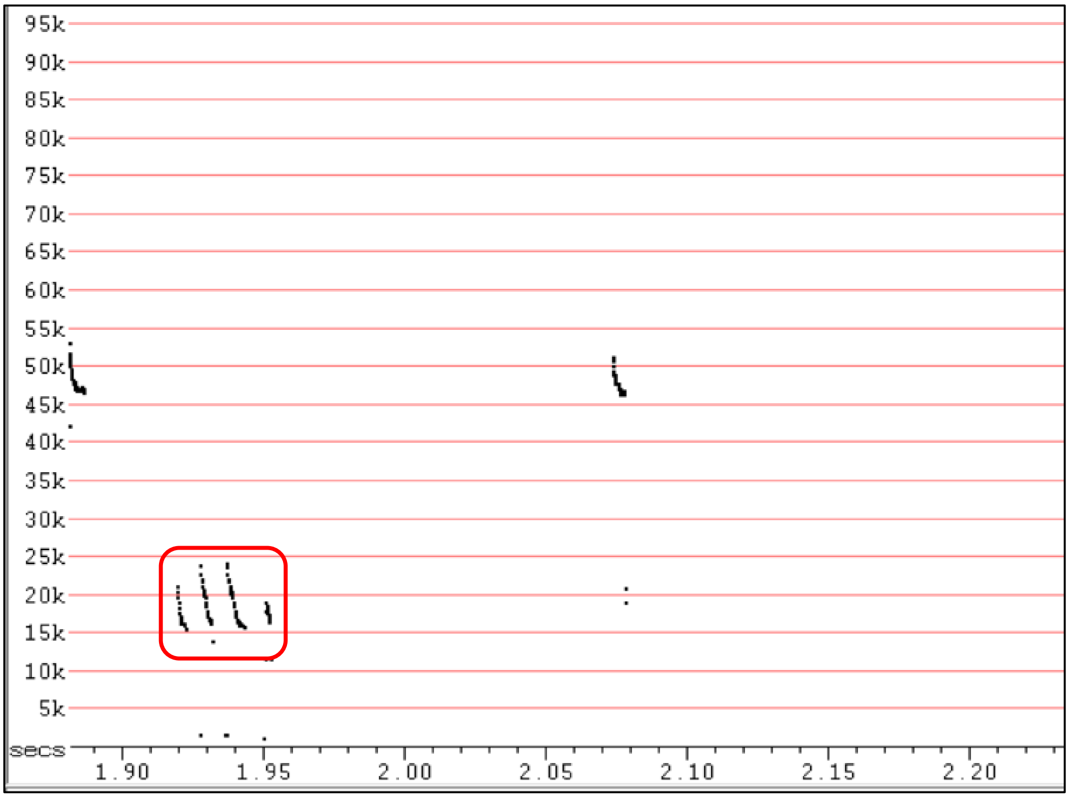


Figure 6: Common pipistrelle type D social call.

Due to a geographic bias of volunteers living on the eastern side of the National Park, a greater proportion of eastern quadrats were sampled (Figure 7). Given this, it would be expected that a greater proportion of east-facing locations would be chosen. However, a variety of aspects were sampled with no significant emphasis towards any aspect (Figure 8).

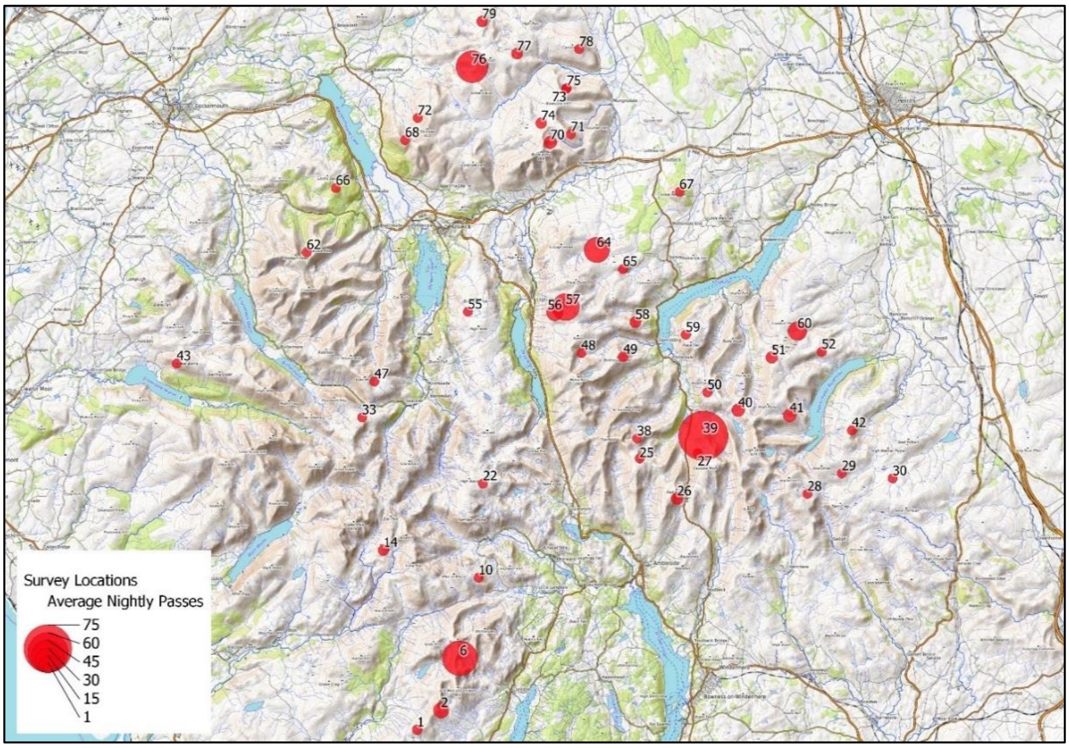


Figure 7: Average nightly passes in surveyed locations.

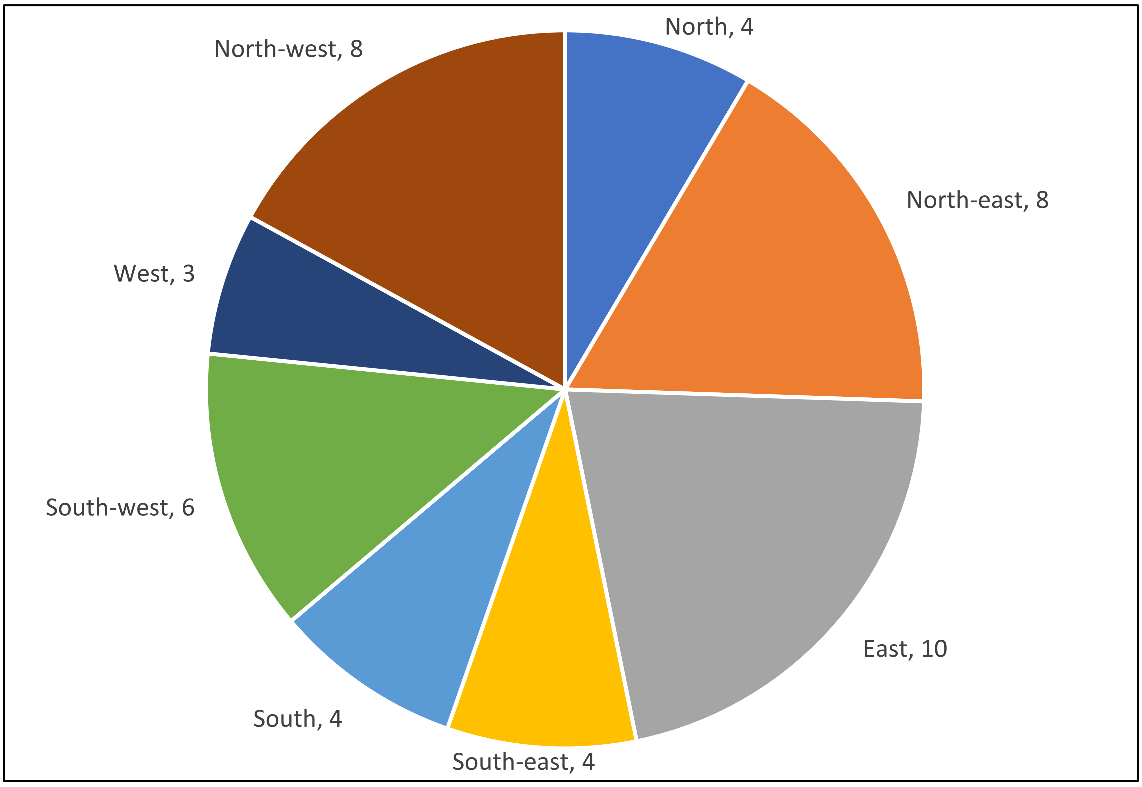
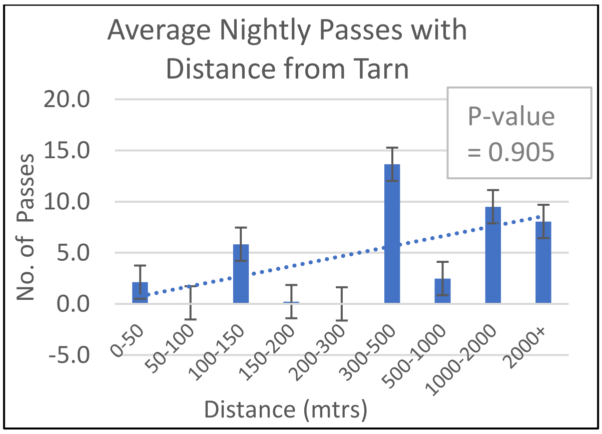
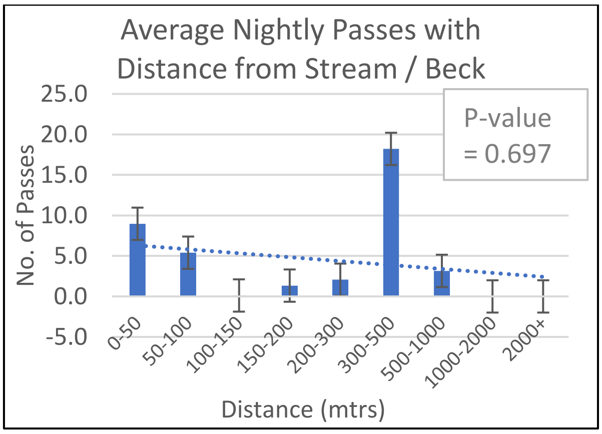


Figure 8: Proportions of aspects surveyed.

Proximity to habitat features were correlated against the mean nightly bat passes, using a one-tailed ANOVA, to establish any connection between habitat and the level of bat activity. Unfortunately, none of the factors returned a p-value of less than 0.05, which would have suggested a significant correlation. The graphs below (Figure 9) show a large variation in the values in all factors, indicating a lack of a trend and therefore a more random distribution. In order to discern whether the weakness of the statistical analysis was due to the small number of values within each category, and therefore a lack of statistical robustness, t-tests were run with the same figures, dividing the results into two categories, 0-500m and >500m. These also did not return a significant figure.





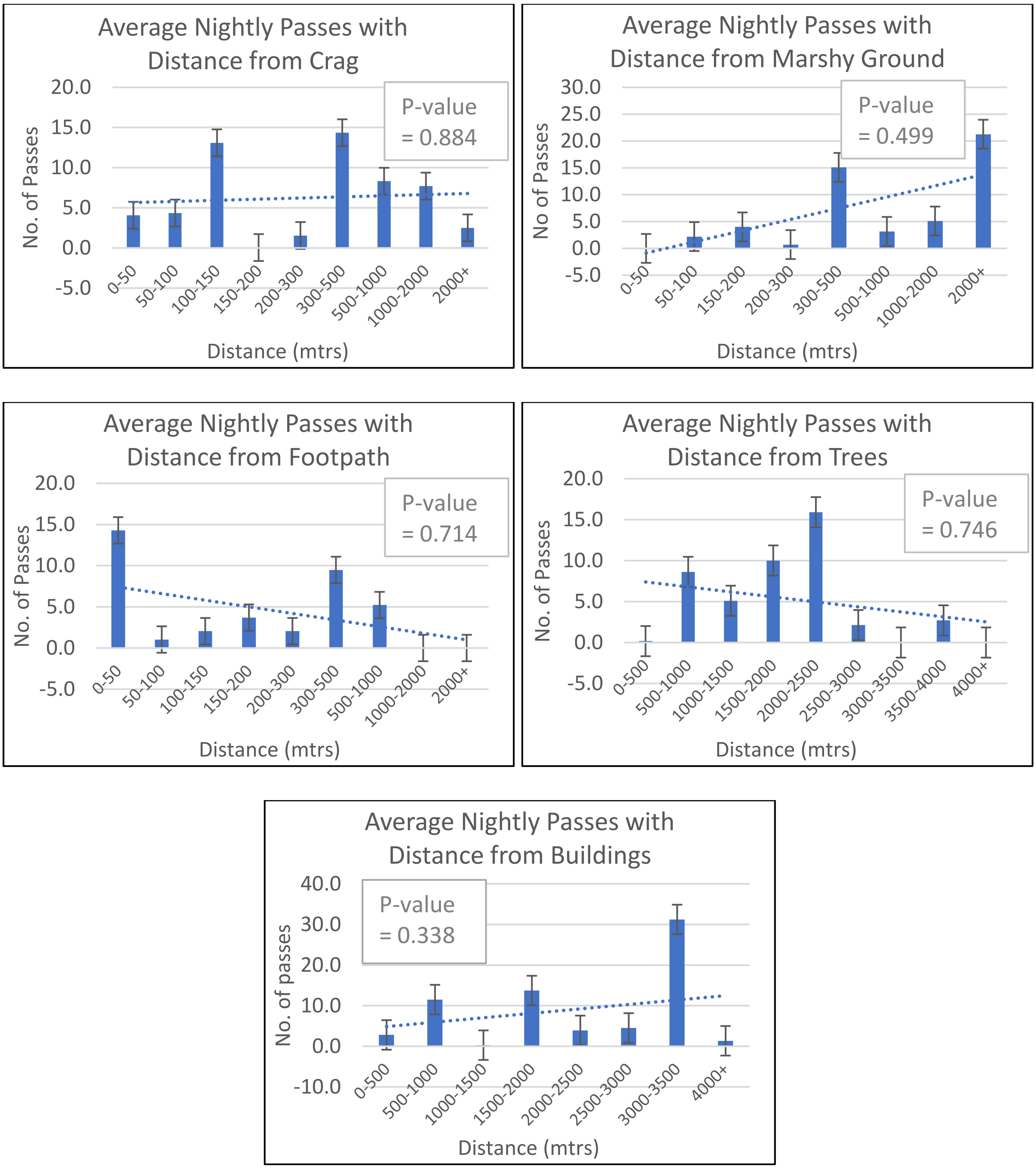


Figure 9: Graphs of average nightly passes against various habitat factors.

In addition, historic rainfall and minimum daily temperatures were correlated against the daily mean number of bat passes using regression analysis. There is a weak to moderate correlation between temperature and bat activity, as can be seen in Figure 10. However, there was no significant correlation between rainfall levels and bat activity, with a figure returned that suggested random distribution (Figure 11).

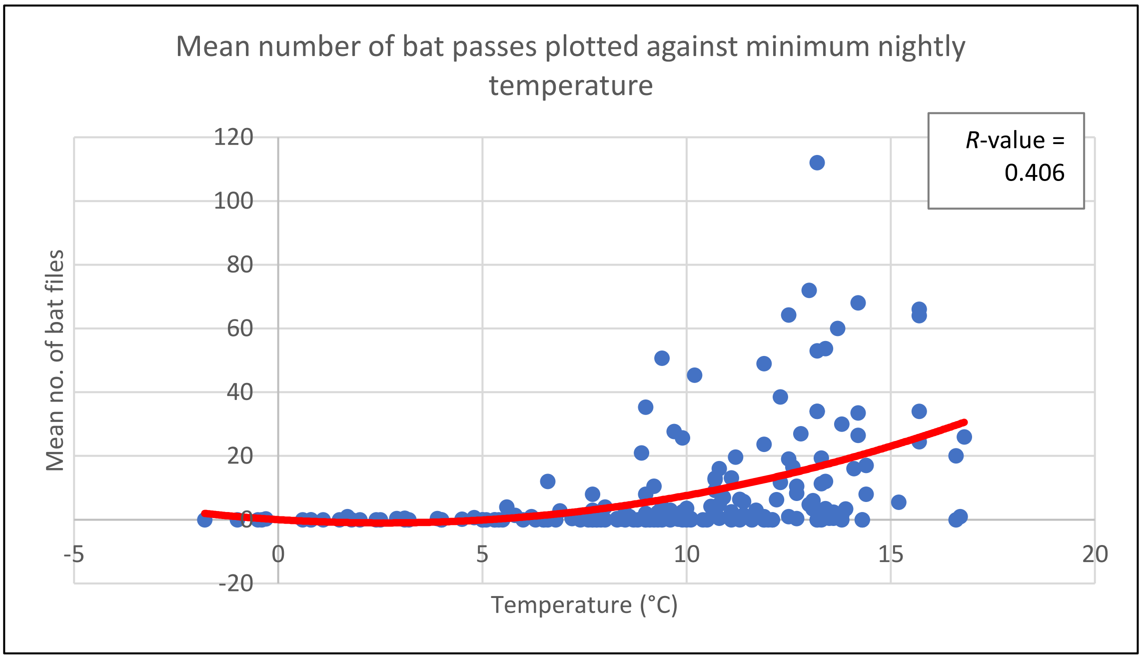


Figure 10: Mean number of bat passes plotted against minimum nightly temperature.

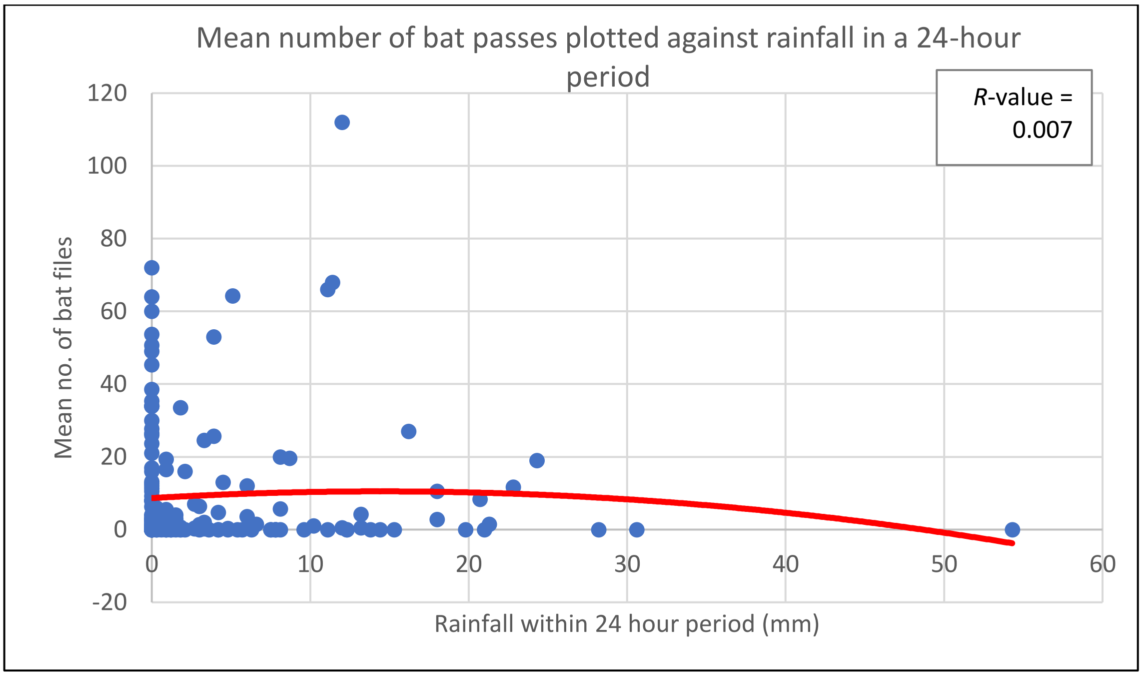
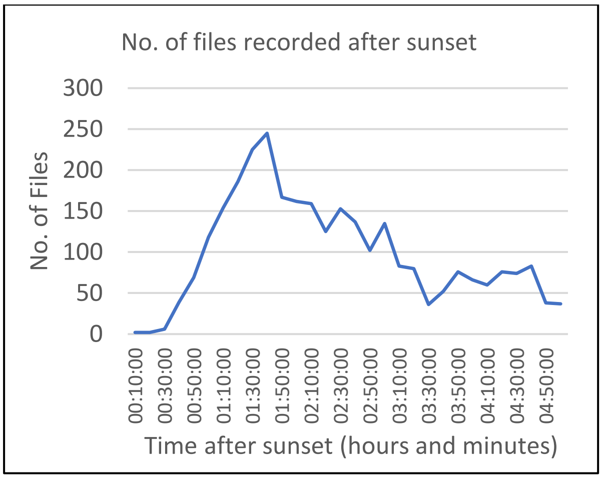


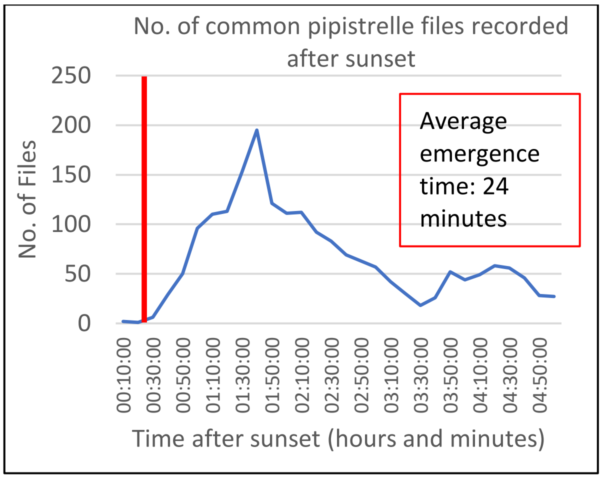
Figure 11: Mean number of bat passes plotted against rainfall in a 24-hour period.

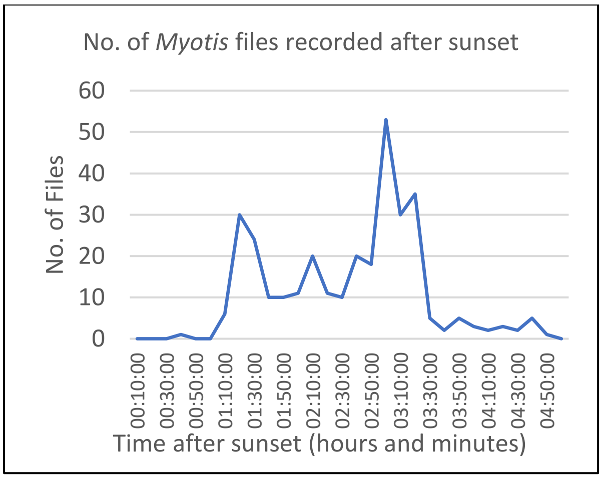
Finally, the time of the first nightly bat recording was examined in relationship to the sunset time. The earliest recording of a bat was a common pipistrelle, recorded at 2 minutes and 54 seconds after sunset, on the 1st August 2016. The table below shows the first recordings of each species, while the graphs within Figure 12 illustrate the recording times after sunset, including the average species emergence time (where relevant).

Table 3: Time of earliest recording, by species.

Species	Earliest 1st Recording (mins after sunset)	Mean Species Emergence Time (MSET)	1st Recording Variation from MSET
Common pipistrelle	2	25 mins	-23
Soprano pipistrelle	14	31 mins	-17
Brown long-eared bat	36	59 mins	-23
Myotis species	38	N/A	N/A
Whiskered/Brandt's bat	39	29 mins	10
Daubenton's bat	46	45 mins	1
Noctule	54	7 mins	47
Natterer's bat	72	54 mins	18
Whiskered bat	78	33 mins	45
Brandt's bat	170	24 mins	146







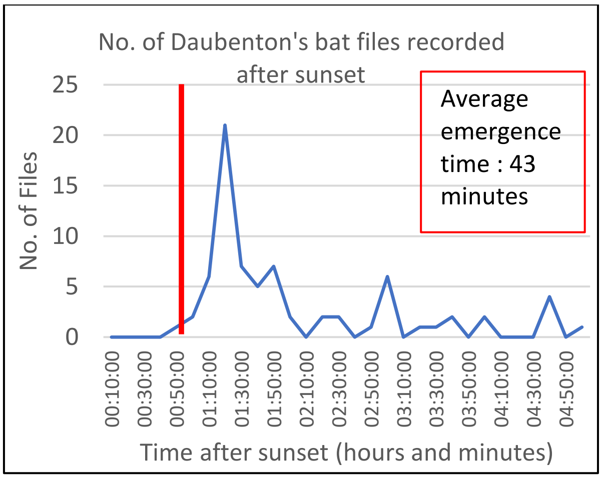
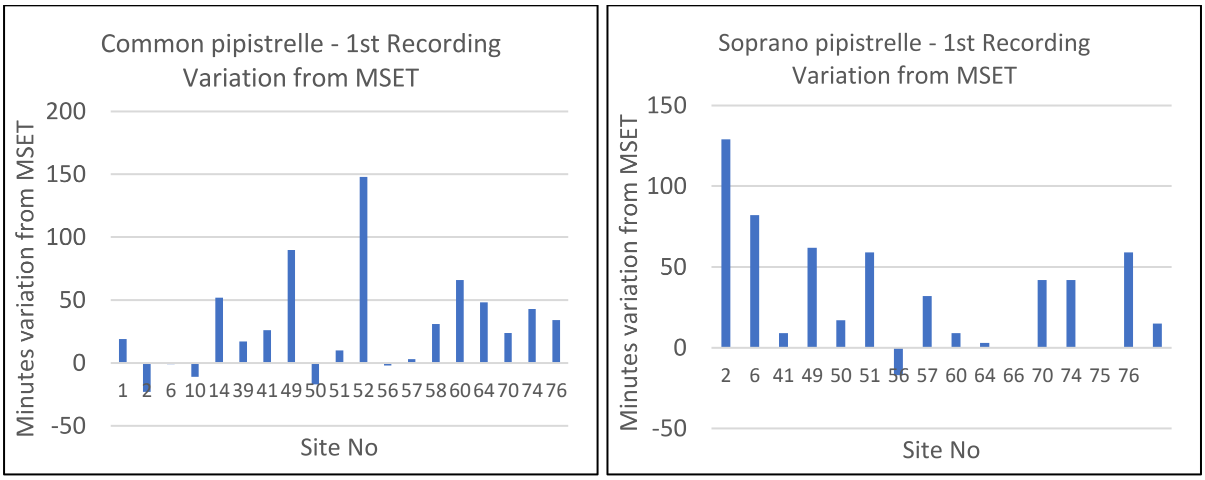


Figure 12: Number of bat passes recorded over time (data pooled over all locations/survey periods).

The majority of the sites, however, did not have significantly early recordings; the graphs below (Figure 13) show the earliest emergence times for four species, in relation to the Mean Species Emergence Time (MSET), at each site where that species was recorded. The majority of the sites display first recording times of well past the MSET.



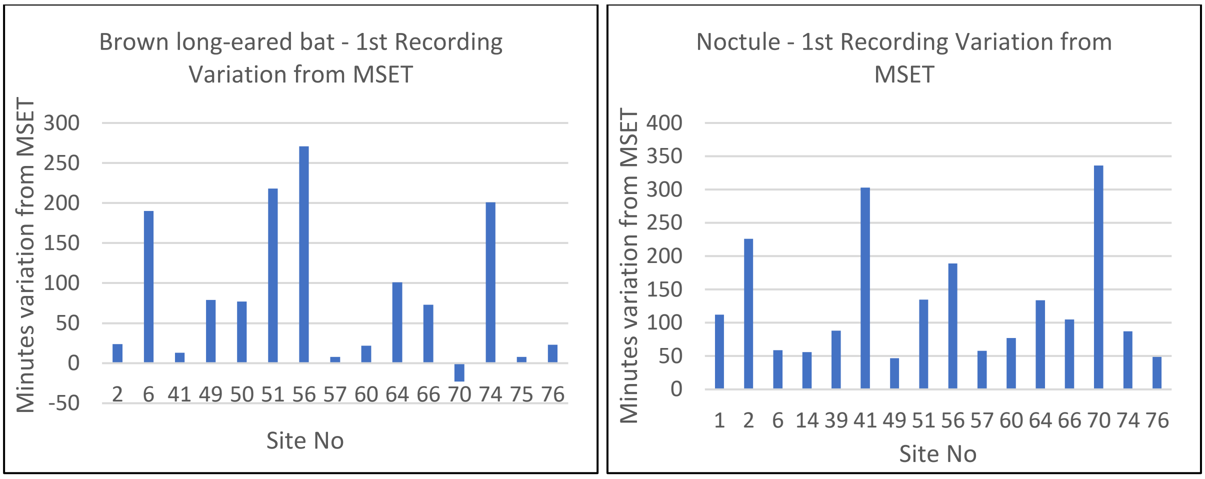


Figure 13: Time of first recording at each site for four species in relation to MSET.

The time of the latest files recorded for each species, those recorded close to sunrise, were also accounted for (Figure 14). Again, the species that were active closest to sunrise were common pipistrelle and soprano pipistrelle bats, the former recording three files that were actually after calculated sunrise time for the day in question. The latest of these three files was two minutes after sunrise on the 24th May 2016. The latest soprano pipistrelle was recorded at one minute before sunrise.

Table 4: Time of last recording, by species.

Species	**Last Recording (mins) in Relation to Sunrise**
Common pipistrelle	-2
Soprano pipistrelle	1
Myotis species	40
Daubenton's bat	40
Natterer's bat	58
Whiskered/Brandt's bat	89
Brown long-eared bat	95
Noctule	102
Brandt's bat	153
Whiskered bat	176

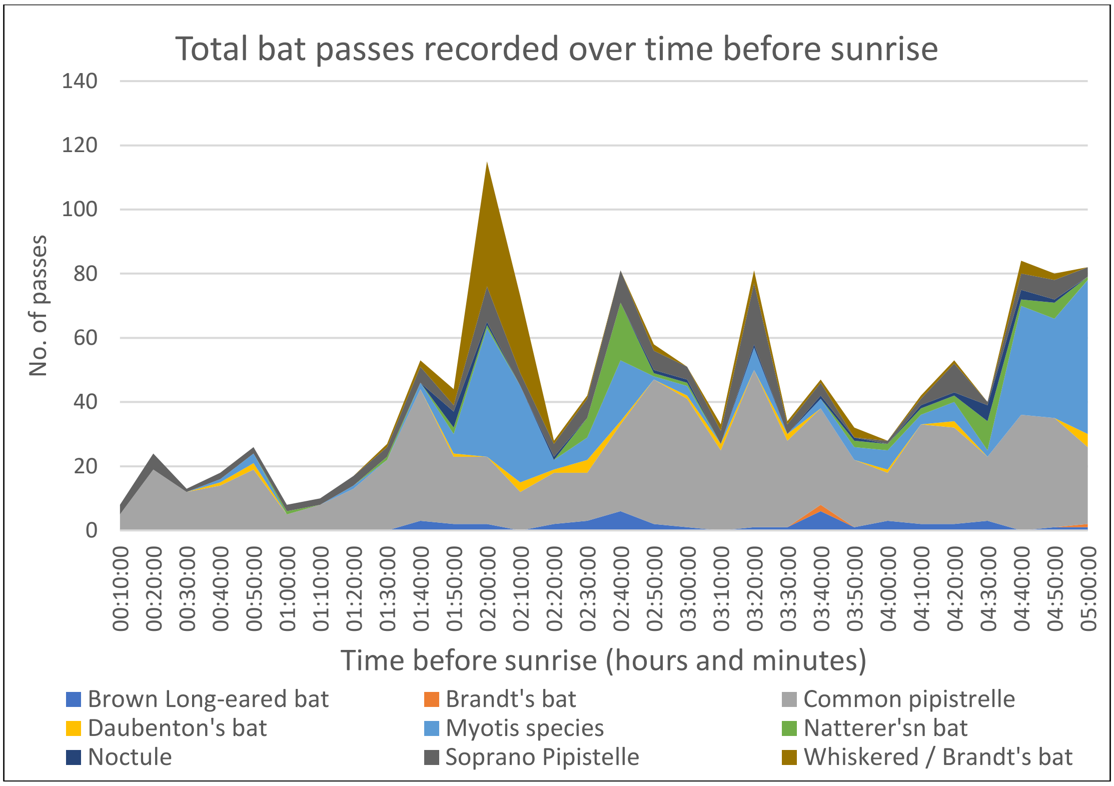


Figure 14: Total bat passes recorded over time before sunrise (Data pooled over total survey period).

Discussion

Presence of Bats

The initial aim of this project was to establish whether British bats could be found foraging and/or commuting within the comparatively harsh environment of the Lake District higher fells. In this respect, the conclusion is resoundingly positive.

With over 4000 individual bat passes recorded on a total of 634 calendar nights, it can be concluded that the presence of bats within the high fells of the Lake District is a feature and not an exception. That said, the presence of bats within the survey data is far from consistent. With an average of just 6.3 passes per night, it is clear that there is not a significant population of bats using the fells. 20 of the 47 sites that were surveyed did not record any bats at all; however, one site recorded 779 bat passes within a 10-day period (this site is examined later in the discussion).

Although the Lake District fells reach a maximum height of 978m (Scafell Pike), the majority of the locations that were surveyed were within the 500-600m band, with 34 of the 47 sites falling within this category. As the project relied on the good will of volunteers, and the Lake District fells are a potentially dangerous environment, it was decided to allow volunteers to decide where they were prepared to position the detectors. This may provide some bias of results and does not conclusively prove that bats can be found on or around the peaks of the highest fells. The highest location to record bats was site 39, which was located at 615m above sea level, close to the summit of Hartsop Dodd; this site was actually the location which recorded the maximum number of bat passes, as mentioned above. Three sites were surveyed at elevations above 615m, but none returned any bat files.

Species

During preliminary visits to the high fells prior to the start of the project, both common and soprano pipistrelle had been encountered, as had Daubenton's bat. As predicted, the two *Pipistrellus* species were the commonest species encountered during the study (ignoring the generic *Myotis* classification). However, common pipistrelle was recorded with a significantly greater frequency than soprano pipistrelle. Within Cumbria, both species are encountered with a relatively similar frequency. Indeed, the largest known roosts in the county belong to soprano pipistrelle and number over 2000 individuals. The dominance of common pipistrelle must therefore be assumed to be due to a habitat or prey preference. As both species feed on small insects, predominately Diptera (Dietz and Keifer, 2016), the latter factor is unlikely to be the dominant force; there is an abundance of small dipterans, including both biting and non-biting midges, within the Lake District fells.

Soprano pipistrelle is known to select riparian habitat over all others (Davidson-Watts *et al.*, 2006), whereas common pipistrelle has been found to be a more generalist forager, utilising a wider variety of habitats and over a wider geographic area (Nicholls and Racey, 2006). Although the high-fell habitat is naturally wet in nature, the watercourses tend to be small and the associated habitats are not typically riparian. It is therefore possible that the more opportunistic foraging strategy of common pipistrelle, combined with their wider foraging ranges, allow them to exploit the mountainous habitat while a greater proportion of soprano pipistrelle remain in the lowland riparian habitats.

Although both *Pipistrellus* species were anticipated, it was not known which of the other eight resident Cumbrian species might be recorded during the project. It seemed unlikely that species such as brown long-eared bat, which favour wooded areas and tend to forage relatively close to their roosts, would be encountered in such open and remote locations. However, the results indicate that all eight of the resident species have been recorded during the project, including brown long-eared bat.

One explanation for the presence of bats outside of their core habitat requirements could be autumn swarming and the reconnaissance of winter hibernation roosts. If this were the case, it would be expected that species like brown long-eared bat and those from the *Myotis* family would be recorded with greater frequency during September and October, when autumn swarming is most active. However, low activity of brown long-eared bat was recorded during every month, from April to September, the most frequently recorded month being April (Figure 15); therefore swarming and reconnaissance are unlikely to be the case with this species.

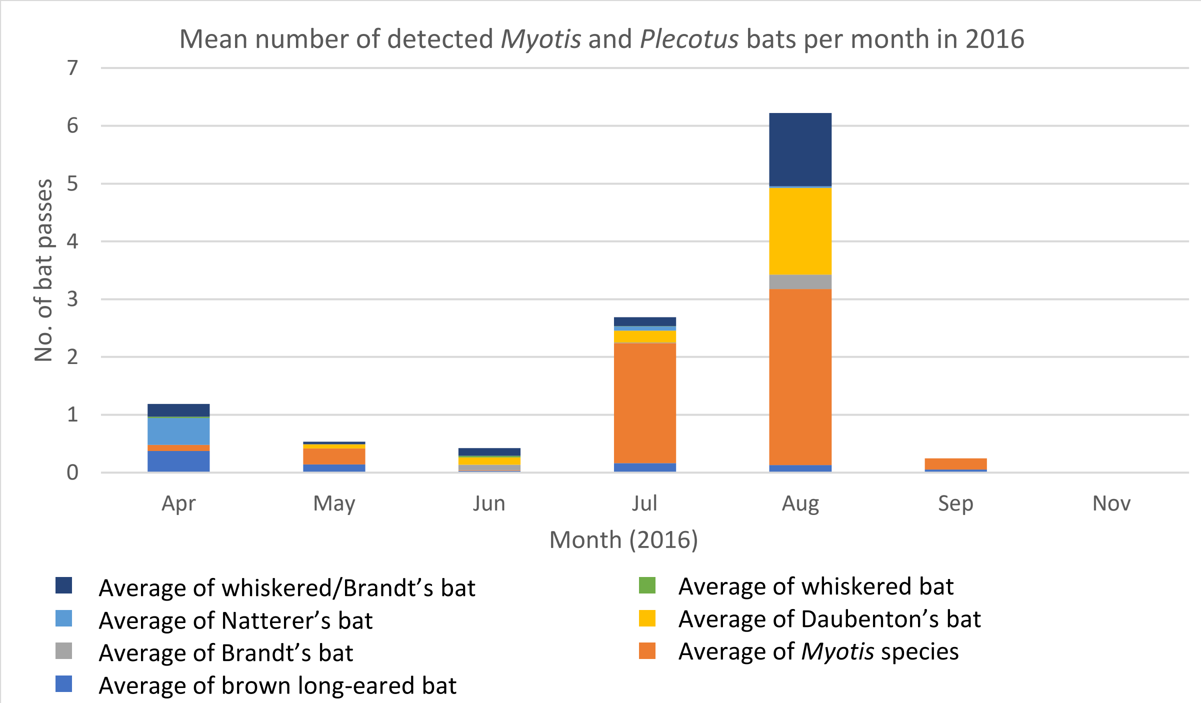


Figure 15: Mean number of detected *Myotis* species and brown long-eared bats per month in 2016.

Conversely, Figure 15 shows that although there is activity by *Myotis* bats throughout the summer, numbers appear to peak in August. This may indeed indicate an increase in activity associated with autumn swarming. During the initial reconnaissance visits to the fells, two hibernating whiskered/Brandt's bats were found in a slate mine on the slopes of Coniston Old Man, approximately 510m above sea level (Figure 16), thus confirming that hibernation does occur in the high fells, where conditions are suitable. Whether conditions would be suitable outside of cave-type locations is debatable. Although crags and rocky outcrops are common in the fells, they often freeze in winter and are exposed to temperatures that drop below -10°C most years.

Figure 16: Hibernating whiskered/Brandt's bat in mine c.510m above sea level*.* © Rich Flight.

Although the increase in activity is not significant enough to indicate a swarming site itself, the detected bats may have been recorded travelling to swarming sites associated with the high fells, such as caves and mine adits. August is relatively early for *Myotis* swarming, which swarm between mid-August and November, peaking in September and October (Rivers *et al.*, 2005). However, bats are likely to undertake a limited migration to these sites prior the swarming event occurring; this may be what was recorded within this study.

An alternative explanation may be that the recorded bats are male bats that are not associated with a maternity roost in mid-summer. These male bats may be out-competed by females and therefore select the less competitive high-altitude habitats. In a study from 2005, Senior *et al.* established that non-dominant Daubenton's bat males were displaced to sub-optimal higher elevation habitats during the summer by females and dominant males. Although this enabled them to feed without overt competition, it reduced their breeding success in the autumn mating period, as they were not as fit as the lowland males that had had access to higher prey density.

It may therefore be possible that the spike in August is a reflection of juvenile bats, which will naturally assume a subordinate position in the population, joining the displaced male bats in these sub-optimal territories.

The least encountered species were whiskered and Brandt's bat; however, this may be a product of the sound analysis strategy. *Myotis* calls were identified to species level when clear and apparent. However, identification was not automated, all calls were therefore manually identified. Any *Myotis* calls with significant cross-over of species was therefore recorded as *Myotis* species only. It is therefore very likely that a significant proportion of the *Myotis* calls could be attributed to whiskered bat and/or Brandt's bat. This error factor is likely to be exacerbated by an element of call modification brought about by these bats flying in a very open and featureless landscape. Therefore, recorded echolocation pulses are likely to be atypical due to the bat's manipulation of their emitted calls in order to compensate for the open landscape.

A previous paper on bat habitat suitability modelling in the Lake District (Bellamy *et al.*, 2013) found a negative association between each of the bat species and elevation, the strongest being found with noctule, which was said to significantly favour lowland sites. In our study noctule was recorded 86 times at 18 sites. However, this was the third lowest, after whiskered bat and Brandt's bat. Given the discussion above, it is likely that noctule may well have had the lowest actual frequency of passes in the study. This is slightly surprising as noctule is a large, strong flying bat which would be able to access the high fells rapidly, even from lowland locations. Bellamy concludes however, that the negative association may be because it is 'a large bat that feeds in the open, it may be particularly prone to climatic effects' (Bellamy *et al.*, 2013).

Timing

The data obtained was not designed to provide any direct information regarding roost sites. However, the timings of the recorded calls provide some indication of the proximity of the roosts to the survey locations. It can be assumed that if bats were roosting near to the detectors then the first recordings of each night would be relatively early. As different species emerge from their roosts at different times, relative to sunset, early emergence would be specific to each species.

The data suggests that some species were recorded very close to, or even before their MSET; the most notable were common pipistrelle (23 minutes before the MSET), soprano pipistrelle (17 minutes before MSET), brown long-eared bat (23 minutes before MSET) and Daubenton's bat (one minute after MSET). As these species were recorded comparatively early, an assumption could be made that these individual bats were roosting relatively close to the detector. For the most part, detectors were positioned a considerable distance from what would be classed as typical roosting habitat (woodland and buildings) and therefore it is possible that these bats were instead roosting in rock crevices within the high-altitude fells.

However, despite these early appearances, the majority of recordings were received after the MSET (Figure 11); the peak of common pipistrelle and Daubenton's bat activity occurred 1 hour and 30 minutes after sunset, while the equivalent peak for both soprano pipistrelle and brown long-eared bat occurred 2 hour and 20 minutes after sunset, both well after the MSET.

Although there is some indication that bats are roosting in close proximity to the detectors, and therefore within the high-fell habitat, the data suggests that these occurrences may be exceptional, and not the norm. It seems far more likely that bats are travelling to the detector locations from further afield. This would account for the delay in activity after sunset that is seen in most species and is even seen in the species that have exhibited occasional early emergences.

With a flight speed of approximately 7 metres per second (Woodland Trust, 2021), common pipistrelle could potentially cover 1km in 2.3 minutes. Naturally, few bats commute in a straight line and fly at top speed the whole time. In addition, it must be assumed that flying up-hill would be more labour intensive and therefore slower than flying across a flat landscape. Even given these restrictions however, there is potentially enough time at most sites for bats to emerge from lowland roosts and commute to the higher altitude locations within the times observed. It is possible therefore, that bats roosting in lowland areas may have an initial feed near to the roost before expending the energy to fly uphill to the more elevated feeding grounds, where they can then replenish their energy levels with little competition.

Habitat

The reason for bats to either roost within habitat which is apparently sub-optimal, or to expend additional energy flying up-hill to these higher altitude locations may be explained by the presence of unexploited prey. The high fells are a damp environment which feature tarns and marshy ground; this is an ideal location for insects, such as non-biting midges (the main prey of the *Pipistrellus* species), to breed in. However, insects in these environments have few predators; during the day they are preyed upon by a small number of birds, such as meadow pipits *Anthus pratensis* and wheatear *Oenanthe oenanthe* but during the night there is likely to be a lack of significant predation. The abundance of available prey in these environments, without any viable competition, must therefore warrant the additional energy expenditure, either in metabolic processes to survive in harsh conditions, or the commuting costs.

Habitat factors were analysed as part of the study, but no significant correlations could be found within the data as a whole. This may be more of a reflection of the statistical prowess of the author rather than the lack of correlation of factors. It is also a reflection of the low sample size. When looking at the categories of distance that were used (0-50m, 50-100m, 100-150m, etc) the sample size was not large enough to provide robust data for each category. Therefore, in each habitat factor, there were categories that had a zero sample size, as well as some categories that were skewed by outlier data.

On a site-by-site basis however, some apparent links can be observed. The site with the earliest emergence of a common pipistrelle was over 2km from the closest building or tree, suggesting that it is unlikely that the bats commuted from these potential roost locations. However, the detector was positioned within 50m of a disused mine shaft, which may well have provided suitable roosting habitat for the recorded bats.

The second earliest recording of this species was eight minutes after sunset (17 minutes before the MSET) at a site that was within 500m of woodland and 950m from buildings. It was also very close to a tarn (freshwater upland pond) which may well have provided a foraging focal point. As previously discussed, a commuting common pipistrelle could hypothetically cover the distance from the nearby trees and buildings in less than two minutes. This was also the site of the earliest soprano pipistrelle recording.

The second earliest soprano pipistrelle recording was from a site within 500m of buildings. Conversely, the earliest brown long-eared bat recordings were from a site that was over

1.5km from any trees or buildings. However, it was within 300m of a crag or rocky outcrop and the second earliest recording was from a site that was within 50m of a crag (but over 1km from trees or buildings).

Without rigorous experimentation (potentially involving trapping and tracking) the connection between these habitat factors are anecdotal at best. However, they provide some explanation for the results received and a possible insight into the habitat usage.

Conclusion

This study was a fact-finding mission; it was not designed to be a comprehensive study into the habitat preferences of high-altitude bats. And as such, the outcome was always likely to involve more questions than answers. However, some definite conclusions can be drawn from the work that was undertaken:

- Bats use high elevation habitats in the UK
- Bats can be found at elevations of up to 615 metres, and possibly higher
- At least eight species of bat can be found in these habitats (all the resident Cumbrian species)
- Common pipistrelle are the most common species to be encountered, followed by soprano pipistrelle
- Bats are known to hibernate in locations as high as 510m

In addition, there are also some inferences that can be made based on the data obtained:

- Some bats are likely to use summer roosts in the high fells
- The majority of bats however, are likely to be commuting to these high-altitude locations from lowland roost sites
- The foraging opportunities that the abundant insect prey provide likely outweighs the energy costs of visiting or living in these areas

Clearly more research is needed if we are to understand how bats use these high environments. There are habitat factors that we have looked at briefly here but not been able to establish a significant correlation between. However, the robustness of the data set is relatively weak, due to the small data sets and the inconsistency between sites, in particular the temporal variation. Although factors such as aspect relative to wind direction, proximity to trees and deep vegetation, and temperature and weather conditions are likely to have an impact on bat presence, establishing the scale of the impact is likely to require a more powerful level of statistical analysis than was employed here.

It is recommended that future research is carried out and could include with following:

- Flight routes of bats commuting to these foraging grounds; do they fly along stream-beds or ghylls? In an open environment such as the fells, ghylls are one of the few landscape features available to navigate by
- A comparison of the call types to establish the proportion of commuting to foraging passes, to determine if the bats are truly foraging in the fells or just using them as a 'short-cut' to reach foraging grounds elsewhere

- Gender segregation within the upland and lowland habitats. Are subordinate males displaced to these sub-optimal habitats by dominant males and/or colonial females?

As a bat group, we hope to return to this study in the future and attempt to answer some of these questions. However, for the meantime, confirmation once again that bats are defying what is expected of them and overcoming barriers to exploit valuable resources is justification for our continued fascination with them. Bats certainly do have serious altitude!

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