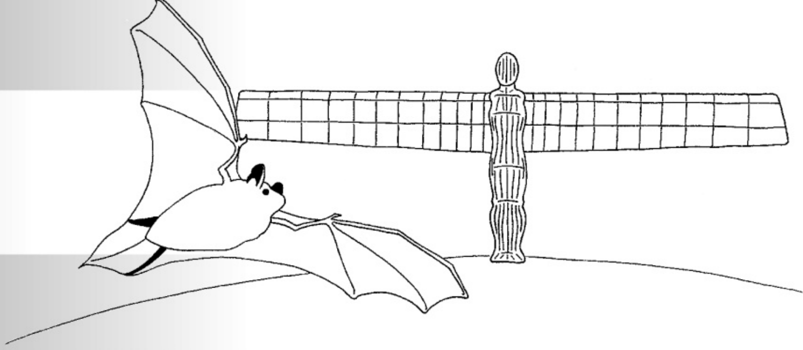
Northern Bats



Northern Bats

Volume 3 May 2018

South Yorkshire Bat Autumn Swarming Study 2017: New Sites and Fresh Questions.

Robert Bell robert.andrew.bell@gmail.com
Ben McLean benjamin.g.mclean@googlemail.com
Peter Middleton pmiddleton630@btinternet.com
Sarah Proctor jaboo004@aol.com
Greg Slack greg.slack@jacobs.com

Introduction

Following exploratory surveys, the South Yorkshire Bat Autumn Swarming Study commenced in autumn 2016. During its first year, the survey focused on catching bats at caves within two woodlands on the belt of Magnesian Limestone which runs north to south through the county. This work was undertaken in order to compare activity levels and gain information on the species, age and sex of bats present. An article detailing the results of the 2016 study was published in Volume 2 of Northern Bats (Bell *et al.*, 2017), with this article including an introduction to the biology of bat autumn swarming behaviour and its study in Northern England.

The 2016 survey confirmed autumn swarming at the three study caves, with 129 bats of five species captured. In order of abundance, species caught in 2016 comprised Natterer's bat *Myotis nattereri*, Daubenton's bat *M. daubentonii*, whiskered bat *M. mystacinus*, brown long-eared bat *Plecotus auritus* and common pipistrelle *Pipistrellus pipistrellus*. Species composition varied between sites; however, the seasonal and nightly variations in activity levels and the sex ratios recorded reflected the results of other studies (Glover and Altringham, 2008; Parsons *et al.*, 2003; Rivers *et al.*, 2006). In a deviation from the expected findings, no Brandt's bat *M. brandtii* were captured during the 2016 survey and in general the proportion of juvenile bats appeared to increase through the swarming season.

The key focus of the 2017 survey was to determine the presence or absence of autumn swarming at four new sites in the county. Whilst two of the new sites comprised caves on Magnesian Limestone, the other two sites are located on different rock types and comprise man-made structures. A second objective of the 2017 survey work was to undertake early season survey work at sites surveyed in 2016, in order to help confirm the presence or absence of autumn swarming Brandt's bat. Finally, a single peak season survey was undertaken at one of the sites surveyed in 2016 (Anston Stones Wood) with the main aim of exploring bat swarming activity at a newly located cave within this woodland (Fissure Cave).

An aerial image showing the study site locations is provided in Figure 1. The location of one of the surveyed sites (Sheffield Mine) is confidential and consequently only its general location is shown. Background information on the study sites and the specific features included within the 2017 survey is provided in the Site Description section of this report.

Figure 1: Map showing study site locations.

Site Descriptions

Anston Stones Wood (included in 2016 survey)

Anston Stones Wood is a 33ha area of mainly limestone woodland, designated as a Site of Special Scientific Interest (SSSI) for its botanical communities. A study of the caves of this woodland, noted the presence of Dead Man's Cave, Fissure Cave and a large fissure (hereafter known as Large Fissure) (Brown, 1968). The two caves and Large Fissure are separated by a distance of approximately 190m.

Dead Man's Cave consists of an entrance fissure, c.2.5m wide and 1.5m high. This leads to a chamber c.4.5m long by 3m wide, with the maximum c.1.5m height located at the entrance. Fissure Cave comprises a c.8m long by 3m high chamber accessed via a squeeze from above. Bat access is also possible via two additional entrance points. Large Fissure comprises an entrance c.3m tall by 0.45m wide. The fissure can be accessed for approximately 6m before continuing for an unknown distance.

To date no hibernating bats have been recorded within either of the two caves or Large Fissure (Bell *et al*., 2017).

Barnburgh Crags (new site)

Barnburgh Crags, also known as Barnburgh Cliff, is a limestone outcrop located along much of Cliff plantation, near Marr, Doncaster. Cliff plantation comprises a broadleaved woodland of approximately 2.8ha. The outcrop is exposed along nearly the whole length of the escarpment (Engering & Barron, 2007). No extensive caves exist; however, a number of smaller fissures are present along the majority of the outcrop, including a single large cut measuring approximately 4m high by 5m wide and 1m deep. A single hibernating brown long-eared bat was recorded in February 2016 (Bell, pers. comm.), roosting within the western of the two narrow fissures, which lead off this cut. Barnburgh Cliff is a Doncaster Council local site[1], which is mentioned within the Local Biodiversity Action Plan for Crags, Caves and Tunnels (Doncaster LBAP, 2007).

Figure 2: Surveyed caves with Dead Man's Cave (Anston Stones) on left, Fissure Cave and Large Fissure (Anston Stones Wood) in centre and the trapped section of Barnburgh Crags on right.

Cadeby Pot (new site)

Cadeby Pot is located to the south of Cadeby village, near Conisborough, Doncaster. The pothole is situated towards the top of a steep limestone escarpment created to the northern side of a gorge cut by the River Don. A group of mass movement caves are known from this section of the River Don valley (Murphy & Cordingley, 2010; Engering & Barron, 2007). This group includes Nearcliffe Wood Rift Cave, located approximately 1.2km east of Cadeby Pot, which was subject to swarming surveys in 2016 (Bell *et al*., 2017). A former railway line, now used as a minor lane, runs directly south of the embankment, with the embankment itself mainly covered by species rich unimproved calcareous grassland.

Cadeby Pot is 45m long and 14m deep. There are two entrances into the pothole with the western entrance trapped during this survey; the west entrance is the main entrance into the pothole with the eastern entrance being much narrower. In 2014 South Yorkshire Bat Group (SYBG) used a thermal camera, infra-red lit video camera and full spectrum bat detectors to first gather evidence of bat autumn swarming at Cadeby Pot. This feature also comprises a known bat hibernation site, with a peak count of a single Natterer's bat recorded from this site in January 2013 (Bell, pers. comm.).

Nearcliff Wood (included in 2016 survey)

Nearcliff Wood is a 21ha area of limestone woodland on the southern side of a gorge cut by the River Don. Part of the woodland is included within the Sprotbrough Gorge SSSI, designated for its botanical and invertebrate communities. Sections of Nearcliff Wood have been subject to extensive former quarrying, resulting in changes to the ground levels. In addition, the woodland is bisected by a gorge cut in the early 1900s for the former Dearne Valley Railway.

A group of mass movement caves are known from this section of the River Don valley (Murphy

[1] Previous known as a Site of Scientific Interest (SSI)

& Cordingley, 2010; Engering & Barron, 2007). Within Nearcliff Wood this grouping includes Nearcliff Wood Rift Cave and a number of smaller caves, associated with the former railway gorge.

Nearcliff Wood Rift Cave is 88m long by 12m deep. It can be accessed by either of the two entrances. The upper and lower entrances both comprise of squeezes separated by a vertical distance of 10m on the steep slope of a quarry face. This feature comprises a known bat hibernation site, with a peak count of a single brown long-eared bat recorded using the cave in January 2017 (Slack, pers. comm.).

Figure 3: Surveyed caves with Nearcliff Wood Rift Cave on left, exterior of Cadeby Pot in centre and interior of Cadeby Pot on right.

Rockley Tramway Tunnel (new site)
Rockley Tramway Tunnel is believed to have been built around 1830 for the transport of coal and goods from Silkstone Colliery to the canal basin at Worsborough. The tunnel was built to take the carriage way drive to Stainborough Castle over the tramway. It is built according to the drystone method by which structures are constructed from stones without any mortar to bind them together. It is 25m long and a little over 2m wide with a height inside of 2m at its highest point. It was first grilled in 1976 by South Yorkshire County Council to protect resident bats from disturbance, but following a number of collapses of the stonework, extensive repairs funded by the council were undertaken in 1988. In total, 6m at the southern end of the tunnel was completely re-built in September and October 1988 and new and stronger grills were installed at both ends of the tunnel.

Rockley Tramway Tunnel has the highest peak count of non *Pipistrellus* species bats recorded from any bat hibernaculum in South Yorkshire (17 bats). Within the Historical County of Yorkshire, this site also ranks second in terms of the peak count of hibernating non *Pipistrellus* species, recorded as part of the National Bat Monitoring Programme (NBMP) (Middleton & Bell, 2017). Bat species recorded hibernating in the tunnel in the recent past include Natterer's bat, Daubenton's bat and brown long-eared bat. Rockley Tramway Tunnel has a long history of bat study dating from the early 1900s, when Arthur Whitaker and Joseph Armstrong first discovered the tunnel and included observations made at the site within papers subsequently published in the Naturalist between 1905 and 1913 (Whitley, 1987).

Rockley Tramway Tunnel is located within Rockley Woods, a mixed woodland designated as a Local Wildlife Site by Barnsley Council (TEP, 2011).

Figure 4: Surveyed structures with the main portal to Rockley Tramway Tunnel on left, the interior of the tunnel in the centre, and the interior to Sheffield Mine on right.

Sheffield Mine (new site)

The mine is located within mixed woodland on an area of sandstone within the Millstone Grit Geology Series. The true purpose of the mine is unknown; however, it is likely to have comprised a source of gannister or pot clay, with these substances used in the steel making process and mined extensively from the wider area during the 19th and early 20th century (Battye, 2004). The mine is not marked on OS Survey Maps and consequently is taken to be at least 150 years old. The passages vary in height and construction but are typically 1.5m in height and the same width, with dry stone supports in some areas and solid stone walls in others. The mine lacks standing or running water but has high humidity and has been subject to historic collapses, which have cut off access to much of its previous extent. Previous inspections undertaken by site owners or their agents, during the last 30 years, showed that this mine previously extended across a number of vertical levels.

Historic bat survey undertaken at Sheffield Mine (Bell, 2016) has shown this feature is used by hibernating bats of one or more species of the *Myotis* genus. Static monitoring survey has also shown it is likely to be used by autumn swarming bats.

Aims

The study aims are given below:

- Demonstrate the presence/absence of autumn swarming at Barnburgh Crags, Cadeby Pot, Rockley Tunnel and Sheffield Mine;
- Gather additional evidence of the presence/absence of autumn swarming Brandt's bat at caves/fissures in Anston Stones and Nearcliff Woods; and
- Assess the relative importance to autumn swarming bats of Fissure Cave, in comparison with the two other surveyed features at Anston Stones Wood (Dead Man's Cave and Large Fissure).

Methodology

Caves at the two locations included in the 2016 survey (Nearcliff and Anston Stones Woods) were surveyed once and twice, respectively, during the early part of the 2017 autumn swarming survey (late July – mid-August). The main purpose of these early season surveys was to establish the presence or inferred absence of Brandt's bat.

Anston Stones Wood was also surveyed once in mid-September in order to gain information on the relative importance of Fissure Cave (a feature not included in the 2016 survey work) and to identify whether bats swarmed at both Fissure Cave and Dead Man's Cave in the same night.

The remaining four sites were trapped once during each of the following trapping periods:

- Mid-season: mid-August – mid September
- Late season: mid-September – mid-October

Surveys were carried out using a pair of three bank harp traps at each site. Both traps comprised Austbat triple bank harp traps. At Nearcliff Wood Rift Cave, one trap was installed across each of the portals; at Anston Stones Wood one trap was installed across the portal of Dead Man's Cave with the second across the fissure-like lower portal of Fissure Cave. At Barnburgh Crags, Cadeby Pot, Rockley Tunnel and Sheffield Mine, one trap was installed across a cave, tunnel or mine entrance with the second trap installed nearby at a vegetation pinch point (Collins, 2016). Where traps were installed across the cave, tunnel or mine opening, the typical procedure was to erect the trap directly across cave opening with additional sections of camouflage netting used to cover the larger spaces between trap sides and the edges of the opening.

Surveyors used hand-held bat detectors (typically BatBox Duet or EchoMeter Touch detectors) to subjectively monitor the level of bat activity around the processing station, harp traps and other nearby areas.

Harp traps were in place from sunset until six hours after this time, with traps checked every 15 minutes during the survey period. The time of each bat retrieval was recorded with captured bats transferred to cotton drawstring bags for transfer to a bat processing area. In the bat processing area bat species, sex, forearm length, age and where possible, breeding status was recorded. Bats were processed in order of capture. Bats were aged as either adults or juveniles, based on the degree of ossification of the joints within the finger bones (Mitchell-Jones & McLeish, 2004).

A fur clipping (Natural England, 2013) was taken from all bats prior to release, in order to allow recaptured bats to be identified. A unique fur clipping pattern was adopted for each site to allow the site of first capture to be determined from recaptured bats. A non-toxic water-based liquid chalk pen was also used to mark the forearm of bats captured (on the second successful trapping session at each site), from the elbow to the wrist. Use of the temporary chalk marking enabled the survey team to establish whether recaptures originated from bats caught twice within the same night or on two different trapping occasions.

Bats were identified to species level with reference to their morphological characteristics, as presented in Bats of Britain and Europe (Dietz & Kiefer, 2016). In order to confirm species identification of suspected whiskered bat /Brandt's bat /Alcathoe bat *M. alcathoe*, clipped fur was retained in a numbered vial for future DNA analysis. DNA analysis was undertaken by the Waterford Institute using a targeted qPCR analysis technique.

To gather additional information on potential swarming at the Rockley Tramway Tunnel site, a Pettersson d500x full spectrum static monitoring device was installed within stonework, approximately 2m in from the grill at the western portal. The Pettersson detector was set with an Input Gain of 100, a Trigger Level of 5 and an Interval of 0 seconds. Sound files of five seconds were recorded. The Pettersson recorded for full days between 26/08-03/09/2017 (inclusive) and 24-28/09/2017 (inclusive). Sound files were analysed using BatClassify auto-analysis software developed by Dr Chris Scott of Leeds University (Scott and Altringham, 2014). A positive identification was considered to comprise a stated probability of occurrence of 0.8 or greater.

Results

Survey observations are broken down by site given the different questions being addressed in relation to each site.

Anston Stones Wood SSSI

No bats were caught at either Dead Man's Cave or Fissure Cave during the late July (25th July), or early August (11th August) survey session. Each of these surveys was compromised slightly at the Dead Man's Cave trap. The first by a 'party' involving lights and loud music, which took place from approximately two to four hours after sunset at a location estimated to be 50m to the southeast of Dead Man's cave. On the second survey, the remains of a fire were present within the entrance to Dead Man's Cave and the smell of smoke persisted throughout the survey. These disturbances were considered less likely to have affected the results at Fissure Cave as the lights, music, and smoke could not be seen, heard or smelt at this location.

The level of bat activity recorded on hand-held detectors at the swarming sites and nearby was extremely low on both early season survey occasions. Given the lack of bat captures and the lack of bat activity, the July and August surveys were called off five hours after sunset.

The third survey, conducted in the second half of September (21st September) recorded a total of 15 bats at Dead Man's Cave and 32 bats at Fissure Cave.[2] The overall sex ratio recorded from Anston Stones in 2017 (87% male; 13% female) is similar to that recorded from the same location in 2016 and fits the expected male bias recorded by similar studies at other swarming sites (Glover & Altringham, 2006; Rivers *et al.*, 2006; Roe, 2016). It was noted that percentage of males caught at Fissure Cave (94%) in 2017 was higher than that recorded from Dead Man's Cave (73%) in the same year. No recaptures were recorded at either the Fissure Cave or Dead Man's Cave traps.

Natterer's bats made up the majority (92%) of bats caught at the two caves (Dead Man's Cave and Fissure Cave) in September 2017. Natterer's bats also comprised most (84%) bats caught at Dead Man's Cave and Large Fissure in September and October 2016 (the survey in late August 2016 recorded a greater proportion of Daubenton's bats and brown long-eared bats). The peak number of Natterer's bats caught in any one night (0-6 hours after sunset), at each feature across the 2016 and 2017 surveys was:

- Fissure Cave – 32 bats (recorded on 21/09/2017)

[2] A single additional adult male Natterer's bat was caught at Fissure Cave at 01:20 (6 hours and 13 minutes after sunset) as the harp traps were being dismantled. As this bat was recorded after the six-hour survey window it is not included in the totals presented.

- Dead Man's Cave - 19 bats (recorded on 07/09/2016)
- Large Fissure – five bats (recorded on 28/08/2016)

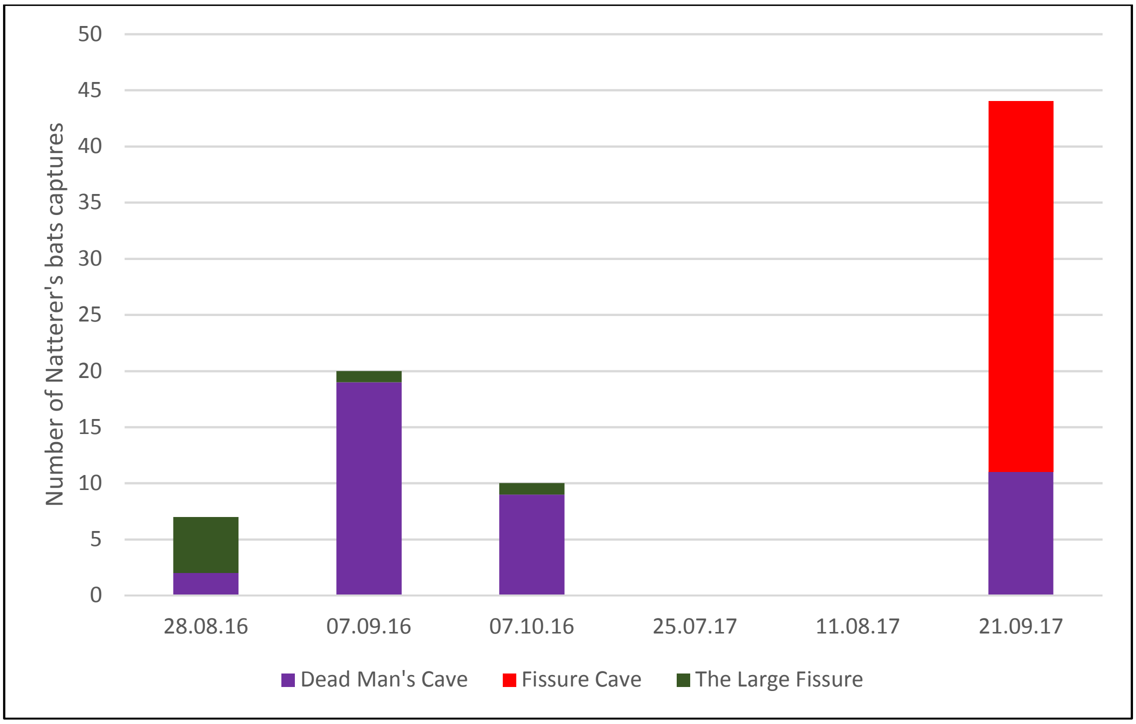


Figure 5: The number of Natterer's bat caught at Dead Man's Cave and Large Fissure in 2016, as compared to the number recorded from Dead Man's Cave and Fissure Cave in 2017.

No Daubenton's bats or brown long-eared bats were caught at Fissure Cave during the 2017 surveys. The number of Daubenton's bats (one bat) and brown long-eared bats (three bats) caught at Dead Man's Cave in 2017 was broadly in line with the mean number caught in September (across two trapping sessions) at Dead Man's Cave in 2016 (2.5 Daubenton's bats and 1.5 brown long-eared bats).

Barnburgh Crags

A total of three individuals of three separate species were caught over two trapping sessions, namely Natterer's bat, whiskered bat and Daubenton's bat. A single juvenile female whiskered bat was caught during the early September session (7th September). Two adult males were recorded during the late September session (22nd September). This resulted in an overall sex ratio of 2:1 male bias. No recaptures were recorded at Barnburgh Crags. All bats were recorded in the trap positioned across the entrance to the cut in the limestone crag.

The juvenile female whiskered bat was recorded approximately two hours following sunset. The adult male Natterer's bat was recorded approximately an hour following sunset and the adult male Daubenton's bat was recorded approximately four hours following sunset. No peak capture rate was recorded at Barnburgh Crags.

Cadeby Pot

A total of 32 bats were captured across both trapping sessions, with 12 bats captured on 09/09/2017 and 20 bats captured on 17/09/2017. Of the bats captured, 25 were caught in the trap positioned across the cave portal and seven were caught at the trap located between a vegetation pinch point at the top of the embankment.

Bats captured comprised Natterer’s bat (19 bats), Daubenton’s bat (eight bats), brown long-eared bat (three bats) and whiskered bat (two bats) (Figure 6). In total, three of the 32 bats captured were recaptures from the second survey. Of the three recaptures the same female Daubenton’s bat was caught twice on the second survey (after previously being initially caught on the first survey); the third recapture was a Natterer’s bat caught twice during the second survey. No other bats were recaptured at this site.

The capture location was heavily weighted to the Cadeby Pot portal, with 78% of all bats being caught at this location (25 bats) and 22% being caught in the trap between vegetation at the top of the escarpment (Figure 6). This bias in capture location is even greater when considering Daubenton’s and Natterer’s bat, the two species most associated with autumn swarming in Britain (Parsons and Jones, 2003). Across both surveys, 88% of Daubenton’s bat and 89% of Natterer’s bat captures were made at the portal; one of three brown long-eared bat captures and neither of the two whiskered bat captures were made at the portal.

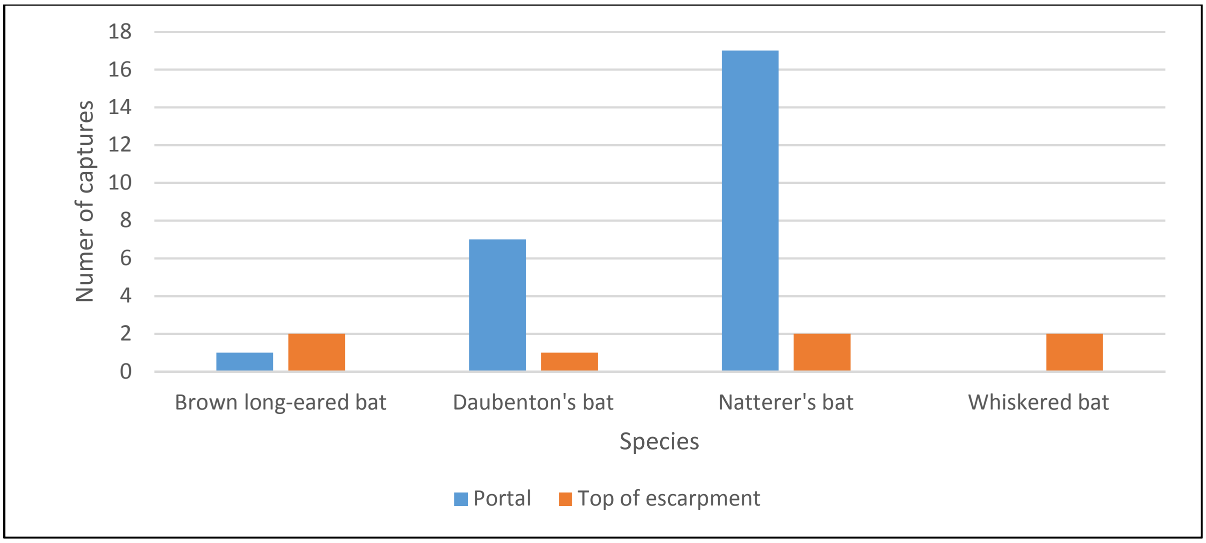


Figure 6: Number and location of bat captures at Cadeby Pot.

Figure 7 shows the breakdown of captures by hour after sunset. This graph shows a clear peak in captures between five and six hours after sunset with 44% of all captures within this period. When the results are broken down by species, the results show that 75% of Daubenton’s bat captures (six of eight bats) occurred between four to six hours after sunset, clearly matching the overall trend. The pattern is different for Natterer’s bat data, which shows two peaks in the number of captures, with the first peak one to two hours after sunset and the second peak five to six hours after sunset. During one to two hours after sunset five Natterer’s bats were caught and during five to six hours after sunset six Natterer’s bats were caught. It is notable that during the first peak, all bats were caught at the portal. The number of brown long-eared bat and whiskered bat captures was low and any patterns in capture times for these species are therefore weak.

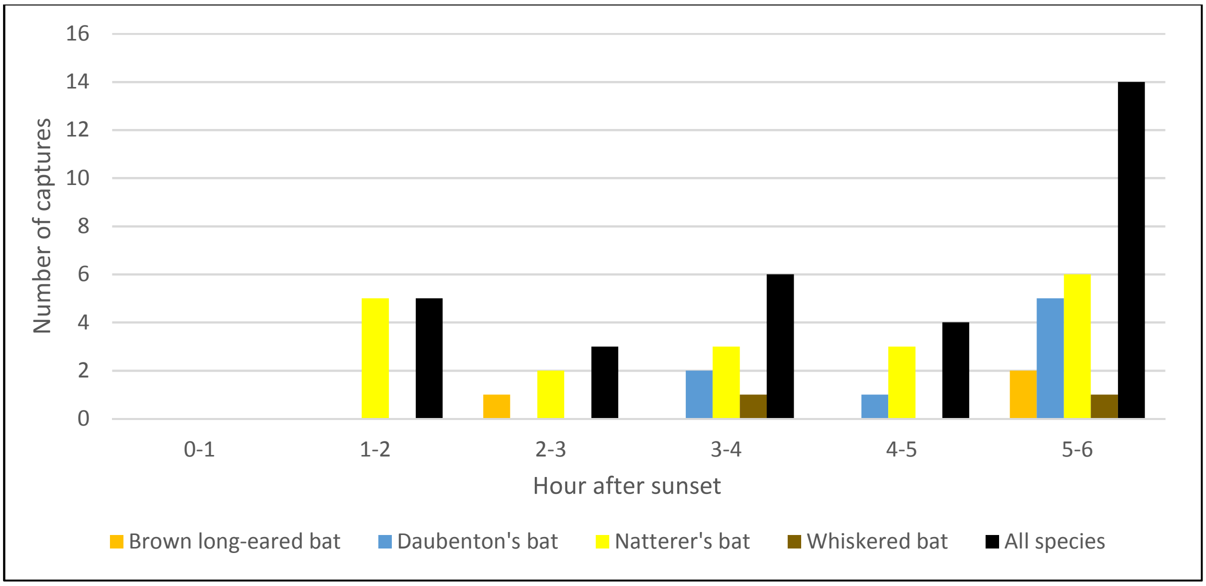


Figure 7: Cadeby Pot captures broken down by time after sunset.

For the purpose of assessing sex ratio, all same night recaptures are excluded from figures within Table 1.

As illustrated within Table 1, the sex ratio was highly skewed towards male bats. Of the total number of bats caught, 77% of bats were male, with all species caught displaying a male bias.

Table 1: Sex breakdown of all captures at Cadeby Pot.

Species	Female	Male
Brown long-eared bat	1 (33%)	2 (67%)
Daubenton's bat	2 (29%)	5 (71%)
Natterer's bat	4 (22%)	14 (78%)
Whiskered bat	0 (0%)	2 (100%)
All bat species	7 (23%)	23 (77%)

Comparison of Cadeby Pot data collect in 2017, with Nearcliff Wood Rift Cave data from 2016

Given the close proximity of Cadeby Pot to Nearcliff Wood Rift Cave it is interesting to compare the findings of the 2017 Cadeby Pot surveys with those made in 2016 at Nearcliff Wood Rift Cave (as reported in Bell *et. al*. 2017).

Based on the comparisons within Table 2, the maximum number of bats caught during a single survey was 20 at both sites. It is noted that the highest number of bats caught at Nearcliff Wood Rift Cave was in late August and we have no comparable data for this period at Cadeby Pot.

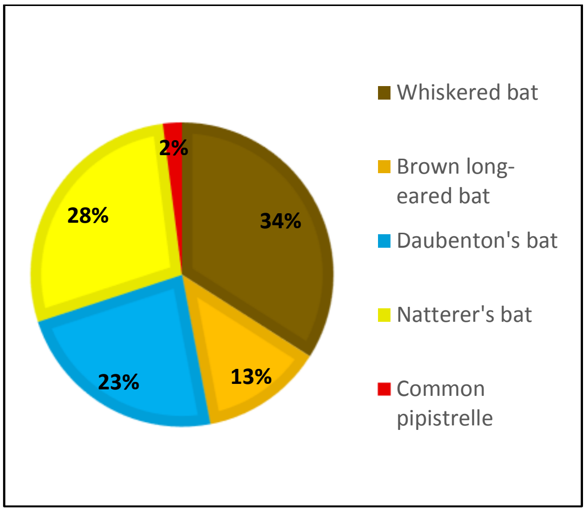
Table 2: Captures at Nearcliff Wood Rift Cave and Cadeby Pot

Sessions	Nearcliff Wood Rift Cave - 2016	Cadeby Pot - 2017
Late August	20	No survey
Early September	12	12
Late September	5	20
October	10	No survey

As illustrated in Figure 8, the relative level of species abundance was not consistent between both sites.

Whiskered bats comprise the most abundant species caught at Nearcliff Wood Rift Cave (34% of captures), but comparably were the species captured in the least abundance at Cadeby Pot (6% of captures). The other major difference between the results of the two sites is the abundance of Natterer's bat caught, with this species making up 23% of the bats caught at Nearcliff Wood Rift Cave but 60% of the bats at Cadeby Pot. The percentages of Daubenton's bat and brown long-eared bats caught were fairly consistent between both sites. At Nearcliff Wood Rift Cave, Daubenton's bat comprised 23% of captures with this species accounting for 25% of captures at Cadeby Pot. Brown long-eared bat accounted for 13% of captures at Nearcliff Wood Rift Cave and 9% of captures at Cadeby Pot.

In addition to the species caught at Cadeby Pot, a single common pipistrelle bat was caught at Nearcliff Wood Rift Cave; although this bat was considered likely to have been foraging rather than swarming.



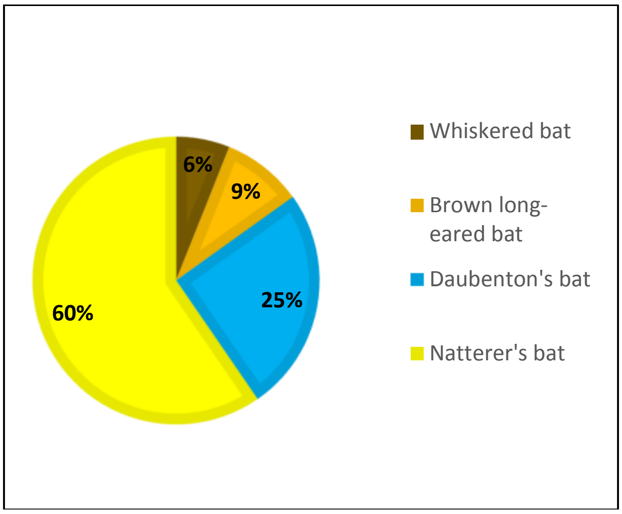


Figure 8: 2016 species composition at Nearcliff Wood Rift (left chart), compared with species composition in 2017 at Cadeby Pot (right chart).

Nearcliff Wood

No bats were captured during the single survey at Nearcliff Wood Rift Cave on 29/07/2017.

Rockley Tramway Tunnel

A total of 35 bat captures were made across both survey sessions, with a far lower number of bats caught on 27/08/2017 (three bats) relative to the 29/09/2017 (32 bats). This finding was made in spite of video evidence that recorded three bats escaping through the harp trap on 29/09/2017. All but one of the bats captured were caught in the trap positioned across the tunnel entrance. Table 3 shows bat captures broken down by species and sex. In total 91% of bats caught comprised Natterer's bats with brown long-eared bat comprising the remaining 9% of captures. Three Natterer's bats were recaptured during the September survey visit, with one bat between session recapture and two within session recaptures.

Of the 32 Natterer's bats caught, 56% were confirmed as female with 41% confirmed as male. A single bat also escaped before it could be sexed. The three brown long-eared bats captured were male.

Table 3: Species composition and sex breakdown from Rockley Tramway Tunnel.

Date	Brown long-eared bat		Natterer's bat		
	Female	Male	Female	Male	Unsexed
27/08/17	0 (0%)	1 (100%)	0 (100%)	2 (0%)	0
29/09/17	0 (0%)	2 (100%)	18 (60%)	11 (37%)	1 (3%)

A consideration of bat capture against time (Figure 9), shows a clear peak for Natterer's bat captures within the period from one to two hours after sunset, with 56% of all Natterer's bat captures within this period. This distribution of activity through the night does not align with bat autumn swarming behaviour and is instead indicative of emergence activity by Natterer's bat. The three brown long-eared bat captures were made throughout the survey period. The observation that bats captured on 29/09/2017 were emerging from the tunnel is supported by video evidence collected from the trapped tunnel portal.

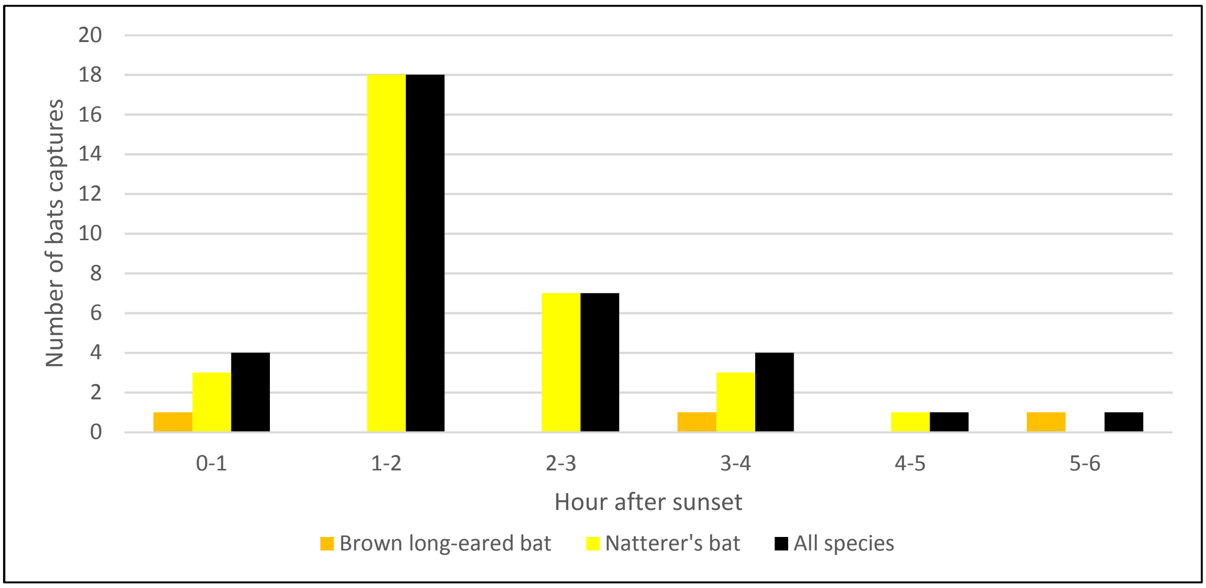


Figure 9: Bat captures by time at Rockley Tramway Tunnel.

Of the 13 male Natterer's bats captured from Rockley Tunnel it was noted that seven (53%) had small testes and small black epididymides. A comparison was drawn with male bats captured at confirmed autumn swarming sites in 2017, with confirmed swarming sites considered to comprise the two Anston Stones Wood caves (Dead Man's and Fissure Cave), and Cadeby Pot. Of male Natterer's bats captured at the confirmed autumn swarming site, only 10 of 63 bats (16%) had small testes and black epididymides.

The findings of static monitoring survey work undertaken at Rockley Tunnel are displayed in Figures 10 and 11. Figure 10 shows the vast majority of sound files recorded from known autumn swarming bat species can be attributed to Natterer's bat (1416 sound files), with a rapid increase in the number of sound files recorded on the night of 27/09/2017. Figure 11 shows that bat activity peaks one to three hours after sunset before dropping then levelling off.

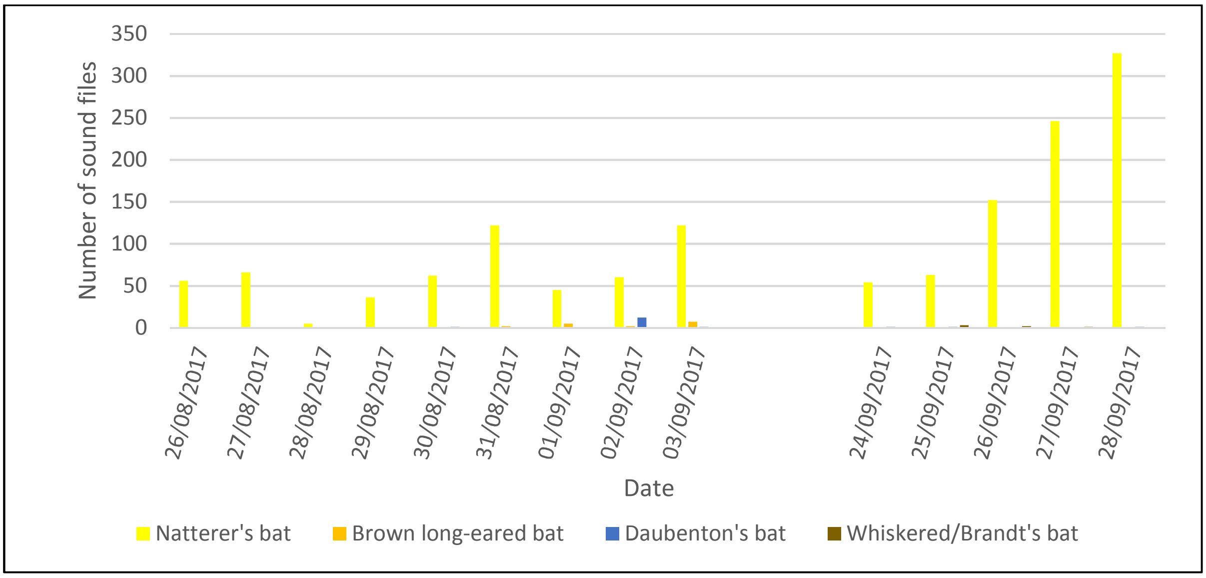


Figure 10: Species composition per night as recorded with a static monitoring device at Rockley Tramway Tunnel.

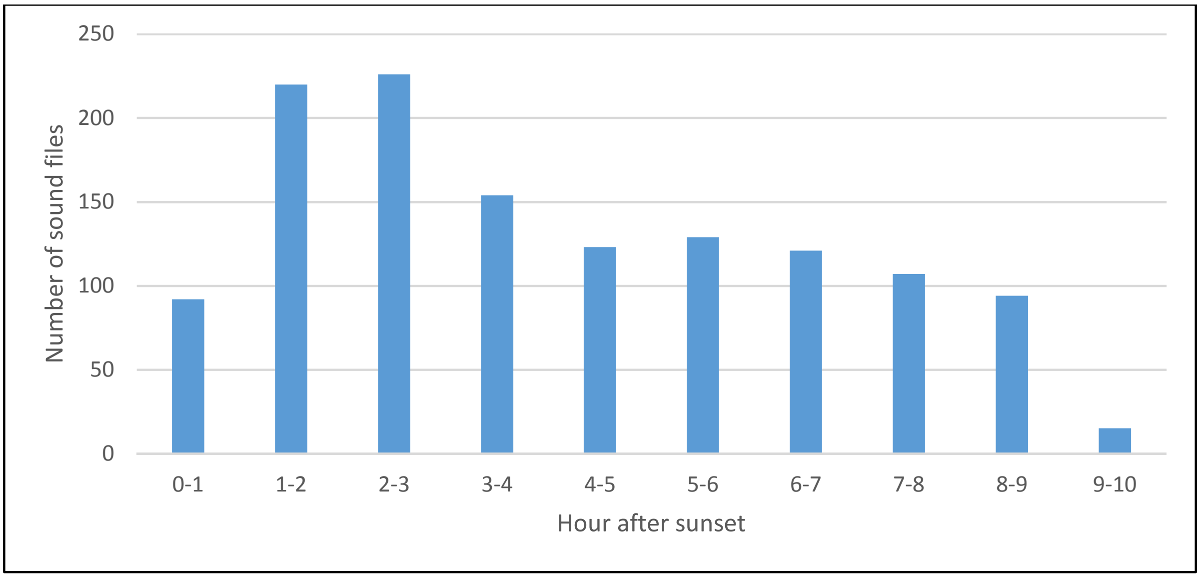


Figure 11: Bat activity distribution through the night recorded from Rockley Tramway Tunnel.

Sheffield Mine
In total, 19 bat captures were made during the standard six hour recording period across both survey sessions, with 10 bats caught on 25/082017 and nine bats caught on 23/09/2017. Nine bats were captured in the trap positioned across the mine portal, with the additional 10 bats captured on a nearby path.

In order of declining frequency, the bats captured comprised Natterer's bat (eight bats), Daubenton's bat (five bats), whiskered bat (five bats) and brown long-eared bat (one bat) (Figure 12). Two of the five whiskered bat captures comprised between-session recaptures. No individuals of other bat species were recaptured at this site.

All Daubenton's bats were captured by the mine trap, whilst Natterer's bats were caught evenly at both trapping locations. All brown long-eared bats and whiskered bats were captured by the trap positioned on the path.

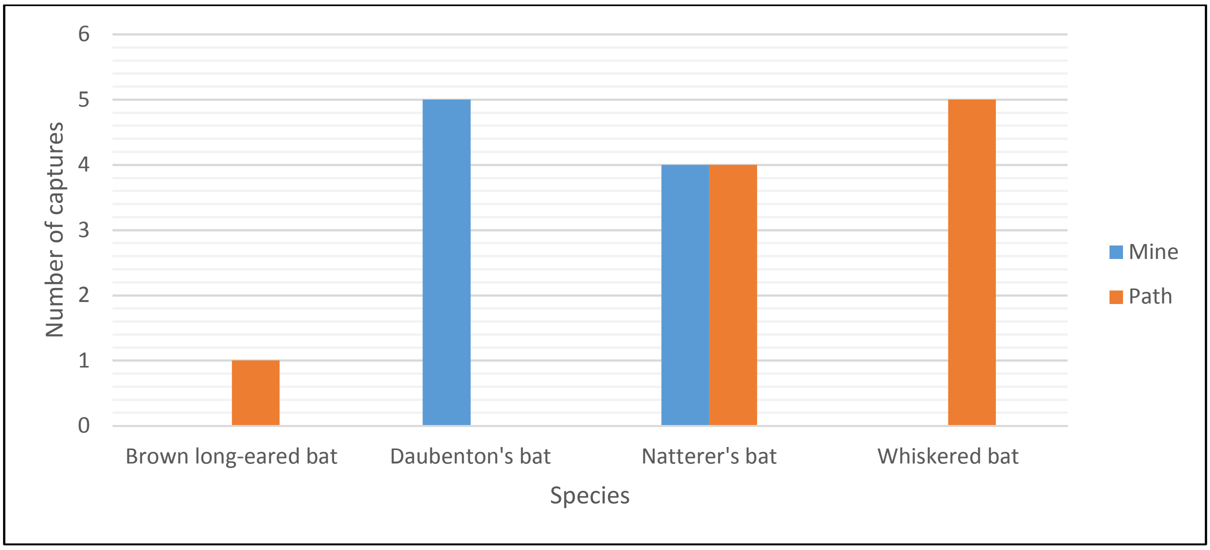


Figure 12: Number of bats caught at each Sheffield Mine trap.

The key aim for the 2017 survey work at Sheffield Mine was to confirm the presence/absence of bat autumn swarming activity at this feature. It is relevant to note, that in addition to the 19 bats trapped during the standard six hour recording period, an additional six Daubenton's bat were captured on 25/08/2017, when the traps were left up for an additional period of approximately 30 minutes. These additional captures are included in the subsequent analysis of capture time and sex ratio, given that they strengthen the data set with which to consider the presence/absence of bat autumn swarming at the site.

Figure 13 shows the breakdown of captures by time after sunset. This graph shows the highest number of captures were made in the third hour after sunset (33% captures), however, the distribution of bat activity throughout the trapping period varied by species.

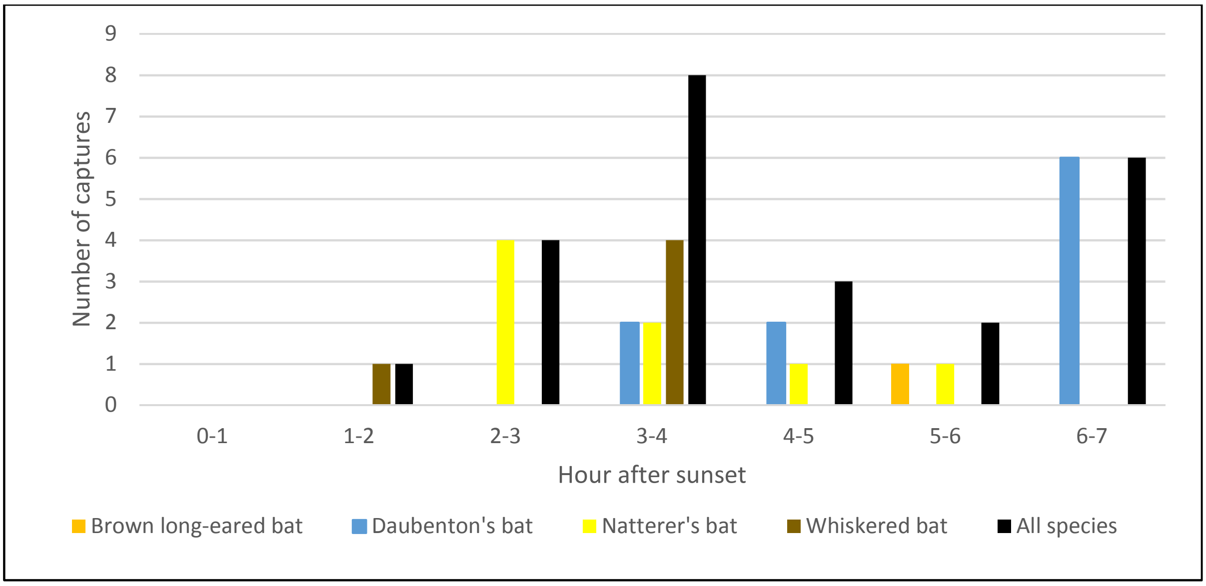


Figure 13: Captures broken down by time after sunset at Sheffield Mine.

Table 4 shows that the overall sex ratio was highly skewed towards male bats (80%). It is however notable that the sex ratio of whiskered bats is relatively even.

Table 4. Sex breakdown of all captures at Sheffield Mine.

Species	Female	Male
Brown long-eared bat	0 (0%)	1 (100%)
Daubenton's bat	0 (0%)	11 (100%)
Natterer's bat	2 (25%)	6 (75%)
Whiskered bat	3 (60%)	2 (40%)
All bat species	5 (20%)	20 (80%)

Discussion

Anston Stones Wood

The 47 bats caught within the six hours after sunset on 21/09/ 2017 was at the time of writing, the most bats caught at any one autumn swarming site in South Yorkshire in one night. Previously in 2016 the Dead Man's Cave and Large Fissure features recorded a peak of 27 bats (all species) (19 at Dead Man's Cave and eight at Large Fissure) between sunset and six hours after this time during the late August survey occasion.

Natterer's bats made up the majority of bat captures at both Anston Stones caves during the 2017 survey. It is worth noting that the trapping is unlikely to capture all bats swarming around a feature, as even where the trap blocks the majority of the entrance, it is possible that bats will avoid the trap or occasionally manoeuvre through the trap. The peak number of Natterer's bats caught at Dead Man's Cave in 2017 (11 bats) was just under 60% of the peak number caught there in 2016. Given that there seems to be little or no interchange of swarming bats between Dead Man's Cave and The Large Fissure or Fissure Cave, it is possible that the number of Natterer's bats swarming across the three features could peak at well over 50 Natterer's bats a night.

The low number of recaptures here in 2016 (Bell *et al*., 2017), at other swarming sites in this study and in other studies (Rivers, Butlin & Altringham, 2006; Glover & Altringham, 2008; Parsons *et al*., 2002) suggests a high changeover rate in the swarming bats. Considering that the Natterer's bat swarming season is likely to extend from mid-August to mid-October with a peak in September, the survey results collected so far suggest that Anston Stones Wood is an important autumn swarming site for many hundreds of Natterer's bats across a season. It would be interesting to identify through future study, the proportion of bats recaptured at the Anston Stones site, if trapping was undertaken on multiple occasions during one week of good weather. If further research demonstrated that a new cohort of bats was present on each subsequent night[3], it would support the assumption that the site was used by a large number of Natterer's bat and increase our understanding of the turnover of bats at swarming sites. Trap placement would need to be considered very carefully to avoid excessive disturbance during the bats swarming activity, while at the same time providing a robust level of bat capture data.

No Brandt's bats have been recorded at features in Anston Stones Wood during any of the surveys undertaken and it is considered unlikely that the site is of importance as an autumn swarming location for this species.

Barnburgh Crags

It is considered the single Natterer's bat caught at Barnburgh Crags is likely to have emerged from the cave due to the time of capture, with Natterer's bats typically emerging late relative to other bat species (median time of 56 minutes after sunset (Swift, 1997)). The Daubenton's bat was captured at a time within the typical nightly peak associated with bat autumn swarming activity (peak activity typically recorded four to six hours after sunset (Parsons *et al*., 2003; Rivers *et al*., 2006)). It is also noted that all bats were captured by the trap positioned across the opening to the crag, suggesting bats were entering or exiting this feature.

Overall, a number of the patterns recorded at Barnburgh Crags, loosely follow those that would be expected at an autumn swarming site, notably including the sex ratio and adult/juvenile ratio. However, all patterns are weak due to the low number of bat captures (three bats). Given the low level of activity recorded at Barnburgh Crags, it is considered that no conclusions can be drawn in regard to whether the site is used by autumn swarming bats.

If further bat autumn swarming survey is to be undertaken at Barnburgh Crags then it would be preferable to use bat static monitoring equipment to survey this area over a longer time period. This approach would provide greater insight into the presence/absence of autumn swarming behaviour at this site, given the apparent low level of activity recorded.

[3] A relatively high capture rate but few or no recaptures during multiple consecutive, or closely spaced, nights of trapping would suggest that a new cohort used the site each night.

Figure 14: The ‘big four’ bat species recorded from autumn swarming sites in South Yorkshire. Top left is Natterer’s bat, top right is Daubenton’s bat, bottom left is brown long-eared bat and bottom right is whiskered bat. Pink chalk markings are visible on the forearms of the Daubenton’s and whiskered bat.

Cadeby Pot

The species captured, nightly activity patterns and sex ratios of bats caught at Cadeby Pot are all typical of those recorded at bat autumn swarming sites (Glover & Altringham, 2006; Rivers *et al.*, 2006; Roe, 2016). These survey findings are considered to clearly demonstrate the presence of bat autumn swarming at this site. It is notable that five Natterer’s bats were captured at the Cadeby Pot portal within one to two hours after sunset. Given the time of capture it is considered probable that these bats emerged from the cave.

Comparison of the results from 2017 survey at Cadeby Pot with 2016 survey observations from the nearby Nearecliff Wood Rift Cave (reported in Bell *et al*., 2017) shows a broadly similar number of captures, but different species composition at the two sites. In addition to these two caves, there are numerous other caves, crags, tunnels, subways and kilns in the Don Gorge (Murphy & Cordingley, 2010; Engering & Barron, 2007; Lane *et al*., 2013), with the location of the majority of these sites shown in Appendix 1.

Given the confirmed presence of autumn swarming bats at both Don Gorge caves studies so far, it is likely that other features within the area would also be used by swarming bats. To gain a greater understanding of bat autumn swarming activity across the wider area, it is proposed that a static monitoring detector survey is undertaken across as many features as possible within the wider Don Gorge during a single night in autumn 2018. This survey method should enable a basic comparison of activity levels at all surveyed features, perhaps leading to the identification of any activity hotspots, which can then be targeted with future trapping survey, if necessary.

Nearcliff Wood

Little can be read into the 2017 survey findings from Nearcliff Wood Rift cave given the lack of captures. These results do however provide some supporting evidence this feature is not used for autumn swarming by Brandt's bat.

Rockley Tramway Tunnel

The 2017 survey findings suggest that Rockley Tramway Tunnel is not used by autumn swarming bats. The observations show that the vast majority of bats caught at Rockley Tunnel were roosting within it, with the captures made on 29/09/2017 showing the presence of a large Natterer's bat transitional roost, comprising at least 26 bats (allowing for two within session recaptures). It is interesting to note that a Natterer's bat maternity roost comprising at least 32 bats is present approximately 900m east of the tunnel, given the close proximity of the two sites, it is possible that the same bats from the same colony use both roosts.

The findings of the static monitoring survey suggest the number of bats occupying the transitional roost is likely to have increased substantially on 27/09/2017, in advance of the second trapping session. The survey findings also appear to show that the typical breeding condition of male Natterer's bats captured at Rockley Tramway Tunnel differs from that of similar bats recorded in 2017 at confirmed swarming sites (Aston Stones and Cadeby Pot). This may suggest the male Natterer's bats captured from Rockley Tramway Tunnel are young or for some other reason not were not in peak condition to engage in autumn swarming behaviour at the time of capture.

The 2017 survey of Rockley Tramway Tunnel was undertaken during the peak autumn swarming period using multiple survey methods, however, no persuasive evidence of bat autumn swarming activity was recorded. It is well documented that bats often swarm and hibernate at the same sites (Rivers *et al*., 2006; Glover and Altringham, 2008) and a study in the Netherlands demonstrated that bat species composition and abundance during swarming can correlate with composition and abundance during hibernation at the same sites (van Schaik *et al*., 2016). On the basis of the 2017 survey findings, it appears that whilst Rockley Tunnel comprises a significant bat hibernaculum, it is not used by autumn swarming bats. Rockley Tunnel appears to comprise an interesting anomaly to the expected pattern that bat hibernation sites are typically also used by autumn swarming bats.

In order to further demonstrate the absence of bat autumn swarming behaviour at Rockley Tramway Tunnel it is proposed to undertake continuous static monitoring survey of the tunnel over the peak 2018 bat autumn swarming period.

Sheffield Mine

The species of bat captured at Sheffield Mine in 2017 comprise those species typically associated with autumn swarming in South Yorkshire (Bell *et al*., 2017), whilst the recorded sex ratio (80%) is highly skewed towards male bats as would be expected from an autumn swarming site (Glover & Altringham, 2006; Rivers *et al*., 2006; Roe, 2016). The peak in nightly activity does not exactly fit the typical four to six hour peak normally recorded from autumn swarming sites with a strong peak in activity between three and four hours following sunset.

This activity pattern does however accord with 2016 survey findings from Nearcliff Wood Rift Cave (Bell *et al*., 2017), at which twin activity peaks were recorded between three and four hours following sunset and five and six hours following sunset.

The 2017 survey results show the sex ratio of whiskered bats at the site is relatively even. In addition, two whiskered bats were recaptured between survey sessions, which is unusual given that recapture rate at autumn swarming sites is typically low (Bell *et al*., 2017; Rivers *et al*., 2006). These two anomalies in the 2017 whiskered bat findings, suggest the whiskered bats captured at Sheffield Mine in 2017 were unlikely to be engaged in autumn swarming on the night/s of capture.

A separate static monitoring survey of Sheffield Mine, undertaken between 07-12/09/2015 (Bell, 2016), recorded a more typical spread of nightly activity for Natterer's bat at the site (peak activity between three and five hours after sunset), alongside an early peak in activity from other *Myotis* bat species (peak activity between two and three hours after sunset).

It is considered the 2017 survey findings persuasively demonstrate that Sheffield Mine is used by autumn swarming bats although the level of swarming activity is likely to be relatively low compared to other sites.

Mining for minerals such as the heat resistant gannister and pot clay took place at numerous locations in the hills around Sheffield (Battye, 2004), fuelled by the growth of the steel production industries. All these mines are now disused and most have been lost to collapse or infilling. Observations made at Sheffield Mine add impetus to efforts to locate any remaining Sheffield mines, in order to determine their usage by roosting or autumn swarming bats. Given that any remaining mines are likely to be at risk of collapse or deliberate closure it is advised that works to locate and survey them should be considered an urgent conservation priority.

References

Battye, R. (2004) The forgotten mines of Sheffield. ALD Design and Print, Sheffield.

Bell, R. (2016) South Yorkshire Mine – hibernation and swarming study findings. Northern Bats Volume 1, available from http://s3.spanglefish.com/s/34944/documents/volume1/south-yorkshire-mine-hibernation-and-swarming-study.pdf

Bell, R., Slack, G., Middleton, P. & Proctor, S. (2017) South Yorkshire Magnesian Limestone Autumn Swarming Survey. Northern Bats. Volume 2, available from http://s3.spanglefish.com/s/34944/documents/volume2/1_south_yorkshire_magnesian_limestone_swarming_survey.pdf

Brown, I.J. (1968) Notes on the caves of Anston Stones near Sheffield. Bulletin of the Peak District Mines Historical Society. 3: 287-289.

Collins, J. (ed.) (2016) Bat Surveys for Professional Ecologists: Good Practice Guidelines (3rd edition). The Bat Conservation Trust, London.

Doncaster Local Biodiversity Action Plan (2007). Crags, Caves and Tunnels: Summary Habitat Action Plan, available from https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=9&ved=0ahUKEwi-jbre8KfYAhUhLcAKHTqFA6cQFghVMAg&url=https%3A%2F%2Fdmbcpublicwebsite.blob.core.windows.net%2Fmedia%2FDefault%2FPlanning%2FDocuments%2FNatural%2520Environment%2FBiodiversity%2FHabitat%2FSummary%2FCrags%2C%2520Caves%2520and%2520Tunnels%2520Summary%2520HAP.pdf&usg=AOvVaw0birjbV9PrNUVDZwCSKK7X

Dietz, C. & Kiefer, A. (2016) Bats of Britain and Europe. Bloomsbury, London.

Engering, S. & Barron, H.F. (2007) Doncaster Geodiversity Assessment. British Geological Survey Commissioned Report CR/07/025N.

Glover, A. & Altringham, J. (2008) Cave selection and use by swarming bat species. Biological Conservation. 141: 1493-1504.

Lane, T., Howes, C., Secombe, P., Hill, L. & Allen, D. (2013) Bat studies in the Don Gorge 1990-2012: the first twenty-three years. The Doncaster Naturalist. Volume 2, Number 3: 89-104.

Middleton, P. & Bell, R. (2017) The Bats of Rockley Tramway Tunnel. The Naturalist. Volume 142: 33-40

Mitchell-Jones, A.J. & McLeish, A.P. (2004) Bat workers manual. Joint Nature Conservation Committee, Peterborough.

Murphy, P.J & Cordingley, J.N. (2010) Mass movement caves in Northern England. Proceedings of the University of Bristol Speleological Society. 17. 2: 105-112.

Natural England (2013) Guidance on the capture and marking of bats under the authority of a Natural England licence. WNL-G39 (10/13), available from http://webarchive.nationalarchives.gov.uk/20140605090108/http:/www.naturalengland.org.uk/Images/wmlg39_tcm6-35872.pdf

Parsons, K.N., Jones, G., Greenaway, F. (2003) Swarming activity of temperate zone microchiropteran bats: effects of season, time of night and weather conditions. Journal of Zoology (London) 261: 257–264.

Rivers, N.M., Butlin, R.K., Altringham, J.D. (2006) Autumn swarming behaviour of Natterer's bats in the UK: population size, catchment area and dispersal. Biological Conservation 127: 215–226.

Roe, S. (2016) Summary Report: Derbyshire Underground Sites Project Phase II. Derbyshire Bat Conservation Group, available from http://www.derbyshirebats.org.uk/swarmpublicationdownloadrequest.php

Scott, S. & Altringham, J. (2014) WC1015 Developing effective methods for the systematic surveillance of bats in woodland habitats in the UK. DEFRA, available from http://sciencesearch.defra.gov.uk/Default.aspx?Module=More&Location=None&ProjectID=17826

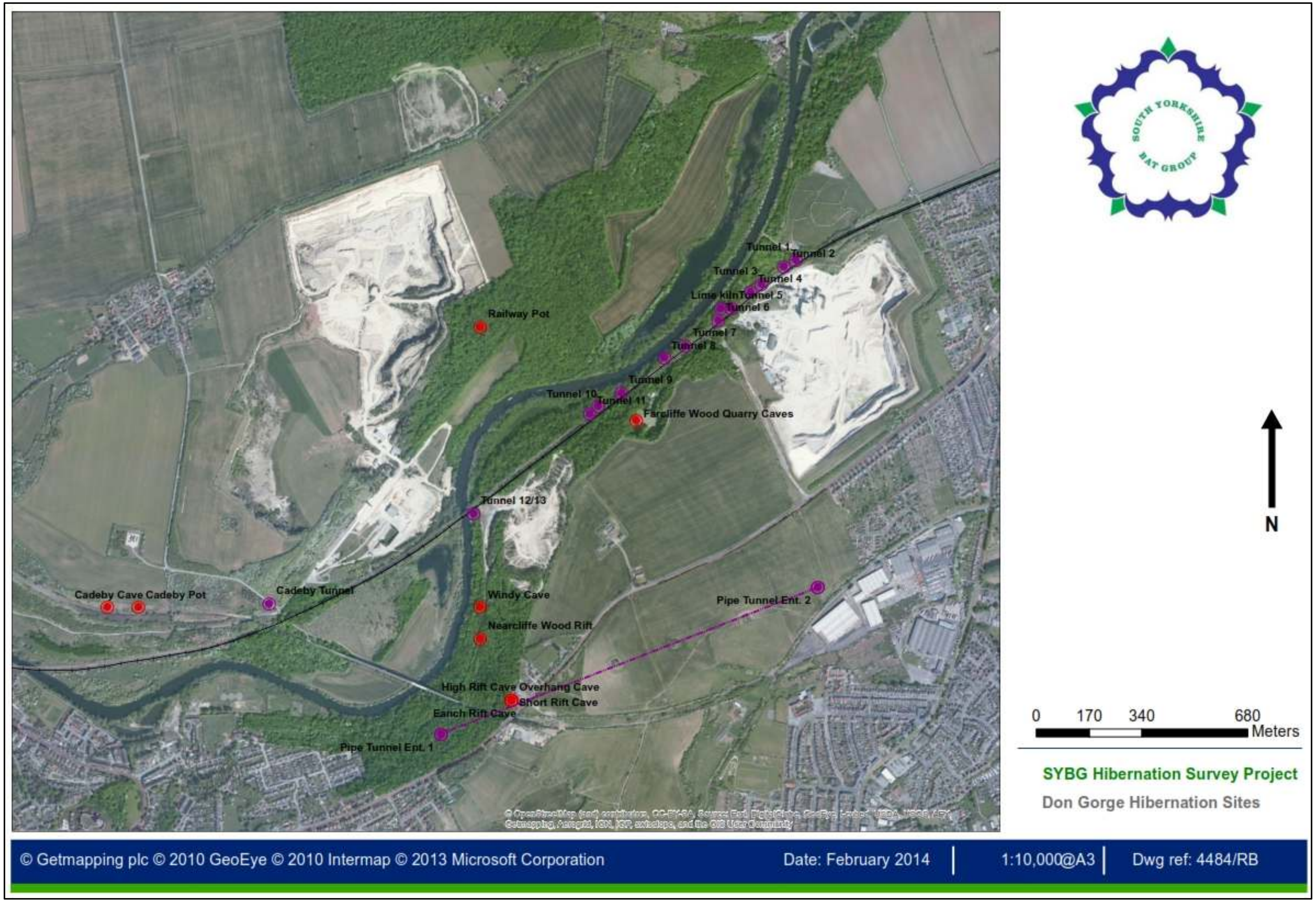
Swift, S. (1997) Roosting and foraging behaviour of Natterer's bats (Myotis nattereri) close to the northern border of their distribution. Journal of Zoology (London). 242: 375-384.

TEP (2011) 23. Rockley Woods LWS Assessment and Phase 1 Survey for Barnsley Metropolitan Borough Council. The Environment Partnership, Warrington.

Van Schaik, J., Janssen, R., Bosch, T., Haarsma, A.J., Dekker, J. & Kranstauber, B. (2015) Bats swarm where they hibernate: compositional similarity between autumn swarming and winter hibernation assemblages at five underground sites. PLoS ONE 10(7): e0130850. doi:10.1371/journal.pone.0130850

Whitely, D. (1987) Arthur Whitaker's Bats, originally published in The Naturalist (1905–1913), Sheffield Bat Group.

Appendix 1. Don Gorge underground sites plan.



A Study of Bat Roosts in Yew Trees.

Ben McLean benjamin.g.mclean@googlemail.com

Introduction

This document presents the findings of a two-year study assessing the use of yew trees *Taxus baccata* by roosting bats. The study involved monthly surveys of the same 73 yew trees at Clumber Park Site of Special Scientific Interest (SSSI).

The aim of the study was to assess the species of bats which roost within yews, the type of roost features used and any seasonal patterns of use. Further analysis could also be made on the regularity of use.

Prior to this study there was little documented evidence regarding the use of yews by roosting bats, with only a single roost of a barbastelle *Barbastella barbastellus* recorded within the Bat Tree Habitat Key (BTHK) by Tom Bennett in November 2015 (Andrews *et al.*, 2016; Andrews, 2018). Since beginning the study, a backdated record of a roosting Leisler's bat *Nyctalus leisleri* from 2003 and a further seven brown long-eared bat *Plecotus auritus* yew roosts have been added to the database (Andrews, 2018).

Site description

Clumber Park is a historic country park and National Trust owned site set in over 3,800 acres. The site is located to the southeast of Worksop in north Nottinghamshire. A key focal point of the site is Clumber Lake which is situated towards the centre of the park. The lake was created in the 17th century through the damming of the River Poulter which runs southwest to northeast through the site.

Clumber Park is a designated SSSI as it is one of the largest areas of mixed habitat in Nottinghamshire, supporting extensive areas of lowland acid grassland, heath and mature deciduous woodland (Natural England, 1999). Managed coniferous woodland and agricultural land also feature throughout the site.

Study description

As with many country parks, mature yews feature throughout Clumber Park. The study focused on three areas of mature yews within the site, all with an uncluttered understorey. A map of the study site locations is provided in Figure 1.

Area 1 comprises 23 scattered yews to the east of Clumber Park. The area is bordered by a very minor road to the north and mature deciduous woodland within the immediate area.

Area 2 comprises a line of 42 yews towards the south of Clumber Park. The line of trees runs adjacent to a footpath, with an area of grazed lowland acid grassland immediately south, scots pine *Pinus sylvestris* managed woodland immediately north and mature deciduous woodland to the east and west.

Area 3 comprises eight scattered yews interspersed to the north, south and west along the main footpath used by visitors around Clumber Lake. The lake is situated to the south and east of Area 3, with deciduous woodland bordering all other directions.

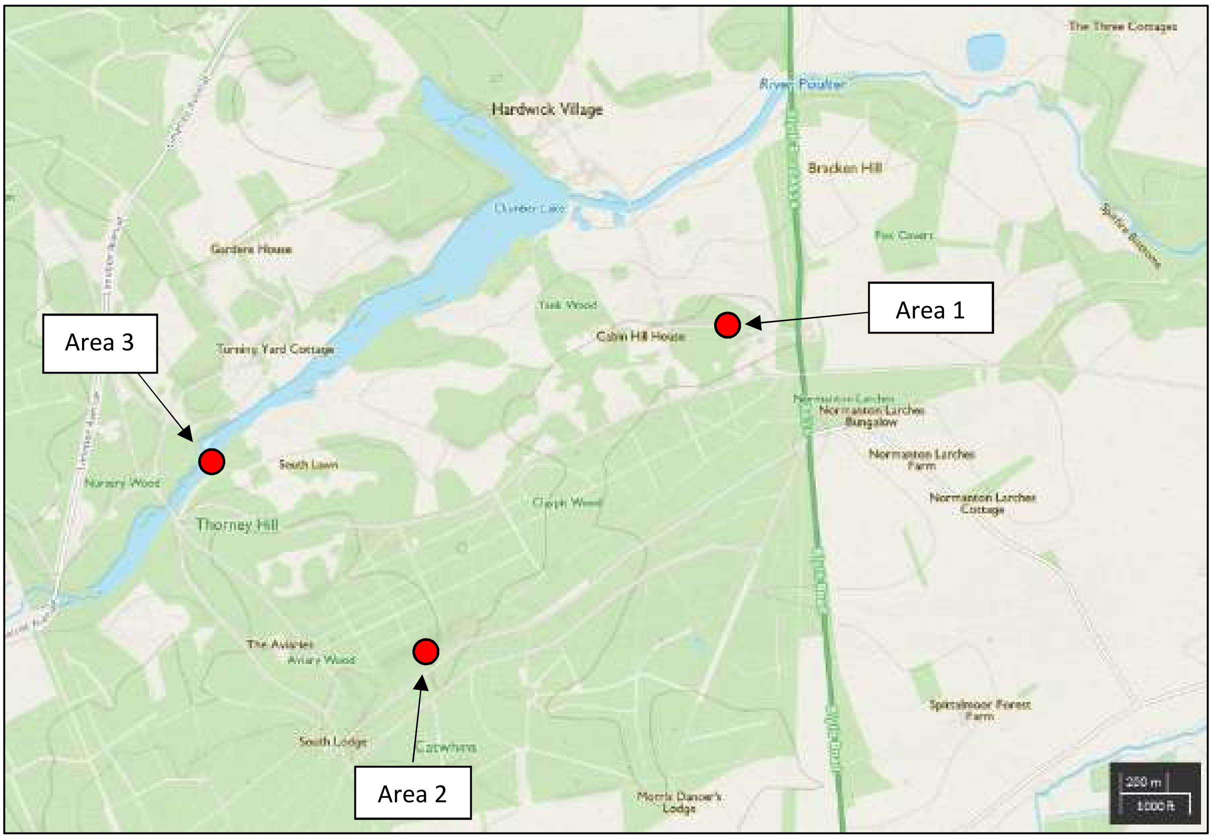


Figure 1: Approximate areas of yew trees within study area (Ordinance Survey, 2017).

Methodology
The survey included a systematic search for bats in-situ or evidence of bats on the same 73 trees on a once monthly basis between March 2016 and February 2018, equating to 24 surveys in total. The trees were predetermined and tagged based on the Potential Roost Features (PRF) and locations of the trees i.e. within close proximities around the site for ease of survey. The trees are split into three separate areas within the site (Figure 1). All trees within the study contain a degree of PRF; yews within the area with no PRF were not included within the study.

The trees were surveyed from ground level only with use of a small LED torch and an endoscope where necessary. The majority of PRF (i.e. fluting) exceed no higher than 3m from ground level, thus the majority of features could be fully inspected without use of ladders. In addition, due to the nature of the type of roosts present, the vast majority of features are fully visible with a torch alone.

Bats were identified to species level with reference to their morphological characteristics, as presented in Bats of Britain and Europe (Dietz & Kiefer, 2016). All data was collected in accordance with the BTHK recording form and submitted to the BTHK database.

It is worth noting that a roost within a hazard beam was lost during the study in October 2017 due to high winds.

For ease of reference the following abbreviations will be used for Tables and Figures within this document: brown long-eared bat = Pa / Natterer's bat *Myotis nattereri* = Mn / common pipistrelle *Pipistrellus pipistrellus* = Pp / soprano pipistrelle *P. pygmaeus* = Ppy

Table 1: Overview of study findings. Number indicates number of bats present (. = possibly 1-2 more bats hidden behind visible bats) Pa Mn Pp Ppy

			2016										2017												2018	
Area	**Tree no.**	**Roost no.**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**
Area a	**T1**	**R1**		1	1																					
	T2	**R2**														1	1									
	T3	**R3**															1									
	T3	**R4**														1										1
	T3	**R5**					1																			
	T4	**R6**	1		1																		1			1
	T5	**R7**		2	1																					
Area B	**T6**	**R8**	1	1																						
	T7	**R9**	1												1	1									1	
	T8	**R10**															2									
	T9	**R11**																						2		
	T9	**R12**												1	1										1	
	T10	**R13**			1																					
	T11	**R14**													1											
	T12	**R15**																				1				
	T13	**R16**						1																		
	T14	**R17**																							6.	4
	T14	**R18**								1																
	T15	**R19**							1																	
	T16	**R20**										1									1	Roost loss due to high winds (hazard beam)				
	T17	**R21**		2						1																
Area C	**T18**	**R22**		1	1						1				1	1					10.		1	1		
	T19	**R23**																								1
	T19	**R24**								1		3	5	2							1					
	T19	**R25**	1																							
	T20	**R26**																						1		
	T21	**R27**																					1			
	T22	**R28**																						1		
	T23	**R29**																						2		
	T23	**R30**						3	1						2						1					

Results

Over the course of the study, 30 PRF were found to support bat roosts within 23 of the trees. Of the 73 trees surveyed, this equates to 32% being found to support a bat roost during this period. Within the 30 PRF, bats were recorded in-situ on a total of 60 occasions.

Roosting bat species recorded during the surveys include brown long-eared bat, Natterer's bat, soprano pipistrelle and common pipistrelle.

Table 1 and Figure 2 provide an overview of all roosts recorded during the study and illustrate the species and number of bats observed and when they were recorded.

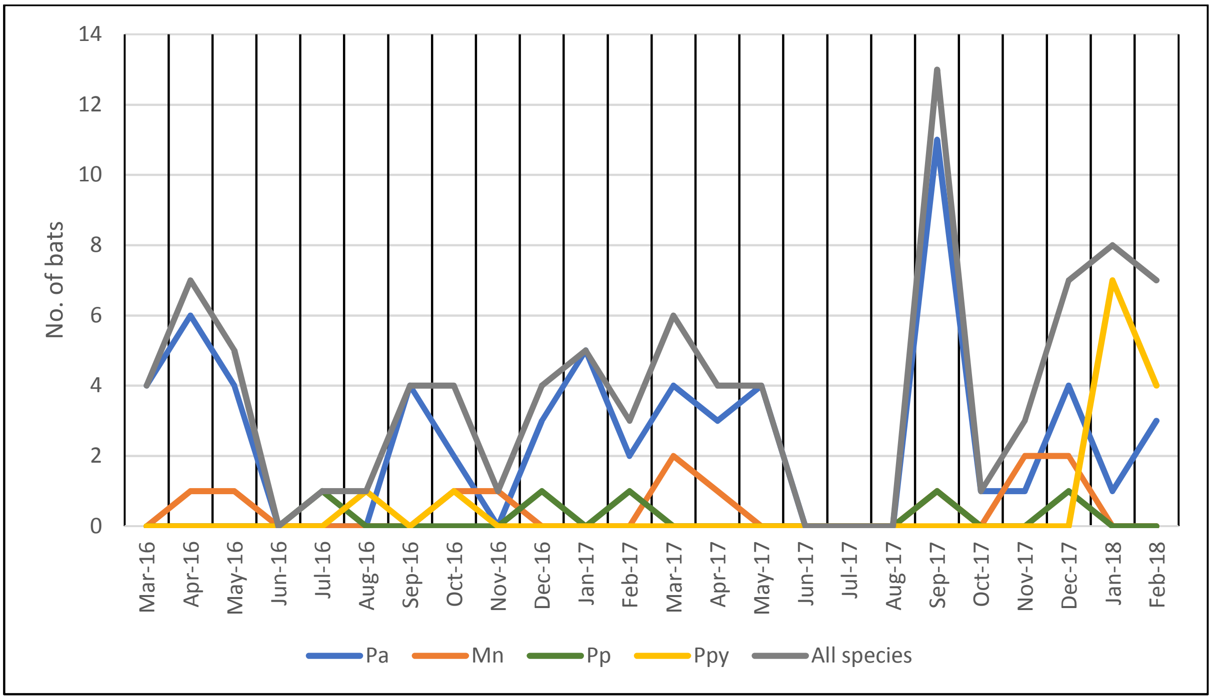


Figure 2: Overview of roost results.

Roost form on yews

Yew trees are native evergreen, non-resinous trees and the trunk is frequently very fluted and/or with multiple and spreading limbs (Thomas & Polwart, 2003). Of the 73 trees surveyed, PRF were recorded in fluting, welds and hazard beams. Fluting was by far the most dominant PRF in the study, particularly considering that some of the yews contained in excess of 10 suitable flutes. In comparison, only a single weld or hazard beam was recorded on any one tree.

Of the 30 roosts recorded, 26 were found in flutes, three in welds and a single roost in a hazard beam. All four species of bat were recorded roosting within flutes; brown long-eared bat was the only species record in welds and common pipistrelle was the only species recorded within the hazard beam.

Brown long-eared bat

Brown long-eared bats, Nottinghamshire and Britain's most common woodland specialist (Harris & Yalden 2008; Bat Conservation Trust, undated; Nottinghamshire Bat Group, undated), was the most recorded bat species in terms of number of roosts recorded, number of occasions encountered and total number of bats recorded throughout the study (it is noted that records may relate to the same individuals being recorded over multiple surveys). Brown long-eared bats were recorded within 21 of the 30 roosts on 38 occasions.

All roosts were recorded in flutes (18 roosts) and welds (three roosts) on the stem of the tree. Roosts ranged from 0.58m to 2.90m from ground level, with an average height of 1.64m. Roosting bats were recorded approximately 4cm to 30cm from the roost entrance of the flutes and 4.5cm to 10cm from the roost entrance of the welds.

Brown long-eared bats were recorded roosting during 17 of the 24 survey days. The only surveys where a brown long-eared bat was not recorded roosting were November 2016 and June, July and August in both 2016 and 2017.

The number of individuals occupying a single roost ranged from one to 10; with a single bat occupying a roost on 27 occasions, two bats occupying a roost on seven occasions, three bats occupying a roost on two occasions and five and 10 bats occupying a roost on a single occasion. Of particular interest were the 10 bats recorded in September 2017 in Roost (R)22, presumably a post-maternity transitional roost. In addition, a hibernation roost was recorded in R24 from December 2016 to February 2017, fluctuating from three, to five, to two bats during this period.

Natterer's bat
Natterer's bats were recorded within five roosts on 12 occasions; of particular note was R22, where a Natterer's bat was recorded on seven separate occasions. A single bat only was recorded on each occasion.

Across the two-year study, Natterer's bat was not recorded roosting during the hibernation period of January and February, or during the main maternity period of June to August; but was recorded at least once in all other months.

All roosts were recorded in fluting on the stem of the tree and ranged from 1.25m to 2.5m from ground level, with an average height of 1.69m. Roosting bats were recorded approximately 5cm to 28cm from the roost entrance.

Soprano pipistrelle
Soprano pipistrelles have been recorded within four roosts on five separate occasions. Three of the roosts were recorded during the hibernation period in 2018 (January/February), with six bats present in R17 in January and four bats present within the same roost in February. In addition, a single bat was recorded in different roosts in August and October 2016 and January 2018.

All roosts were recorded in fluting on the stem and ranged from 1.25m to 2m from ground level, with an average height of 1.53m. Roosting bats were recorded approximately 3cm to 10cm from the roost entrance.

Common pipistrelle
Common pipistrelles have been recorded in four roosts on five separate occasions. Roosts relate to a single bat present and were recorded in July and December 2016 and February,

September and December 2017.

Three roosts were recorded in flutes on the stem and one roost was recorded within a hazard beam. A common pipistrelle was recorded roosting within the hazard beam on two occasions; however, this feature was lost to high winds in October 2017.

The roosts within fluting ranged from 1.25m to 1.89m from ground level, with an average height of 1.63m. The roost within the hazard beam was 1.02m from ground level. Roosting bats were recorded approximately 7cm to 15cm from the roost entrance of the flutes and 11cm to 12cm from the roost entrance of the hazard beam.

Mixed roost
No roosts were found to support multiple species at the same time.

Three roosts were found to support more than one species of bat but at different times.

Roost 12 was found to support a single Natterer's bat, common pipistrelle and soprano pipistrelle on separate occasions. All species were only observed on one occasion.

A single Natterer's bat was observed within R22 on seven occasions and 10 brown long-eared bats were observed within the same roost on a single occasion. A bat roost was recorded within R22 on eight occasions making it the most regularly occupied roost during the course of the study.

A single Natterer's bat was observed within R24 on two occasions, with brown long-eared bat recorded on three consecutive surveys from December 2016 to February 2017 (three bats, five bats and two bats).

Seasonal use
Figure 3 illustrates the average number of roosts recorded each month over the two-year study.

March, April and May were the most productive months in relation to number of roosts observed, with an average of four or more roosts recorded per month.

The least productive months with regard to number of roosts recorded were June, July and August with an average of less than one roost recorded per month. No roosts were recorded in June during either year and only a single bat was observed in July and August; with a common pipistrelle recorded in July 2016 and a soprano pipistrelle recorded in August 2016. No brown long-eared bats or Natterer's bats were recorded during these months.

An average of two to three and half bat roosts were recorded per month from September to February over the course of study.

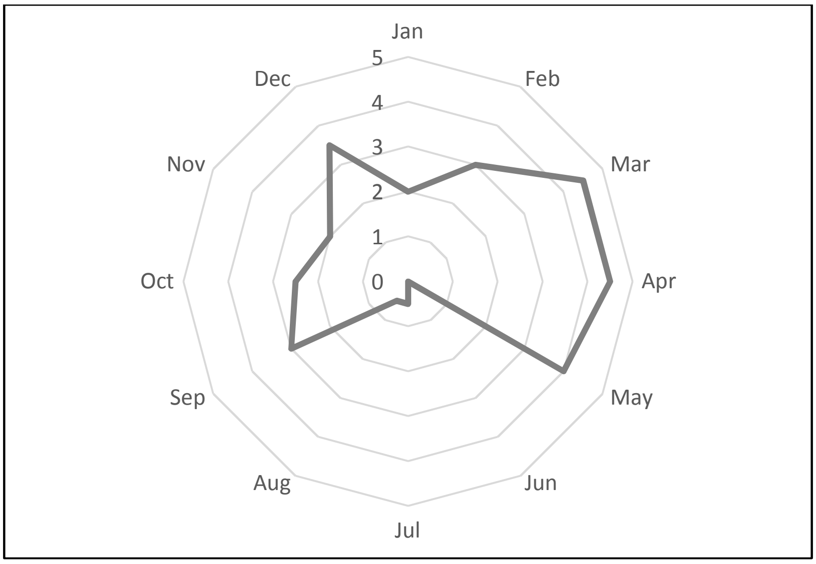


Figure 3. Average number of bat roosts (all species) recorded per month.

Area

Of the three areas of yews surveyed, the percentage of trees found to support a bat roost was considerably higher in Area 3. With comparison to the three areas, 75% of trees within Area 3 were found to support a roost, with 22% and 29% of trees found to support a roost in Area 1 and Area 2 respectively (Table 2).

It is also worth noting that four of the five trees supporting a Natterer's bat roost and 11 of the 12 times Natterer's bat were encountered, occurred within Area 3. In addition, all brown long-eared bat roosts occupied by three or more bats were recorded within this area.

The substantial difference in percentage of tree roosts within Area 3 may partly be attributed to the relatively small sample size within this area; however, habitat is also considered to be a contributing factor.

Area 3 is situated immediately adjacent to Clumber Lake and is fairly central within the park. In comparison, Area 1 and Area 2 are located approximately 550m and 1km from Clumber Lake respectively. The proximity to water and associated high density of invertebrates is likely to be a contributing factor to the noticeable difference in percentage of roosts recorded in Area 3. Furthermore, the increased occupancy of PRF within proximity to water reflects the results of studies by Kalcounis-Ruppell *et al.* (2005).

Table 2: Roosts recorded within each area.

Area	Total number of trees in area	Number of trees with roosts in area	Percentage of trees in area with roosts
Area 1	23	5	22 %
Area 2	42	12	29 %
Area 3	8	6	75 %

New roosts
Figure 4 illustrates the number of new roosts recorded each month.

Records of new roosts ranged from zero to four per survey (with an average of 1.25 new roosts recorded per survey). Over the course of the first year of the study (March 2016 to February 2017) a total of 17 new roosts were recorded, with 13 new roosts recorded in the second year (March 2017 to February 2018). New roosts were recorded right up until the last survey (i.e. 24th visit).

A total of four new roosts were recorded during three surveys. Two of these surveys relate to the first two months of the study, March and April 2016. A peak in these two months is largely due to lack of any previous information on roost locations in the study area, however, these two survey occasions also fall within the flux period, a time of high roost occupation (Figure 3). Of greater interest, the third month during which four new roosts were recorded was December 2017, the 22nd survey repeat undertaken during the study.

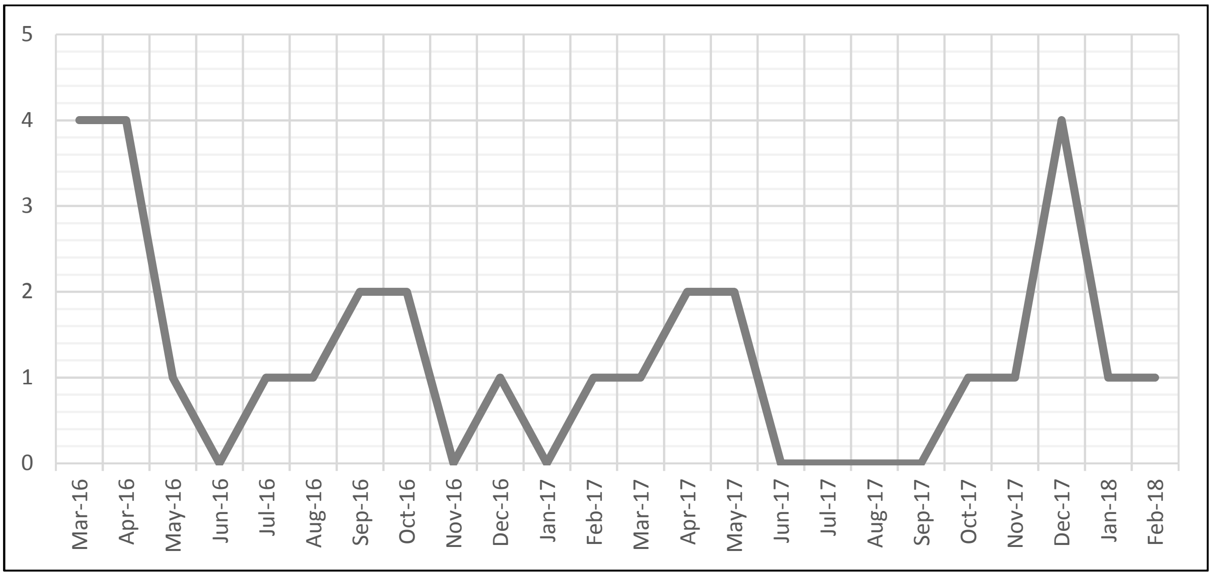


Figure 4: Number of new roosts recorded per month.

Rate of roost occupancy
Of the 30 roosts recorded, 53% were occupied on a single occasion only over the 24 survey visits.

The roost with the highest occupancy, R22, had a single Natterer's bat present on seven occasions and 10 brown long-eared bats on a single occasion. Although it cannot be confirmed, it is considered likely that the Natterer's bat was the same individual recorded on multiple occasions, showing high fidelity to this roost.

Although data was gathered on a once monthly basis and provides only a snapshot of roost switching behaviour, the study does highlight that the majority of roosts recorded are used on a relatively infrequent basis.

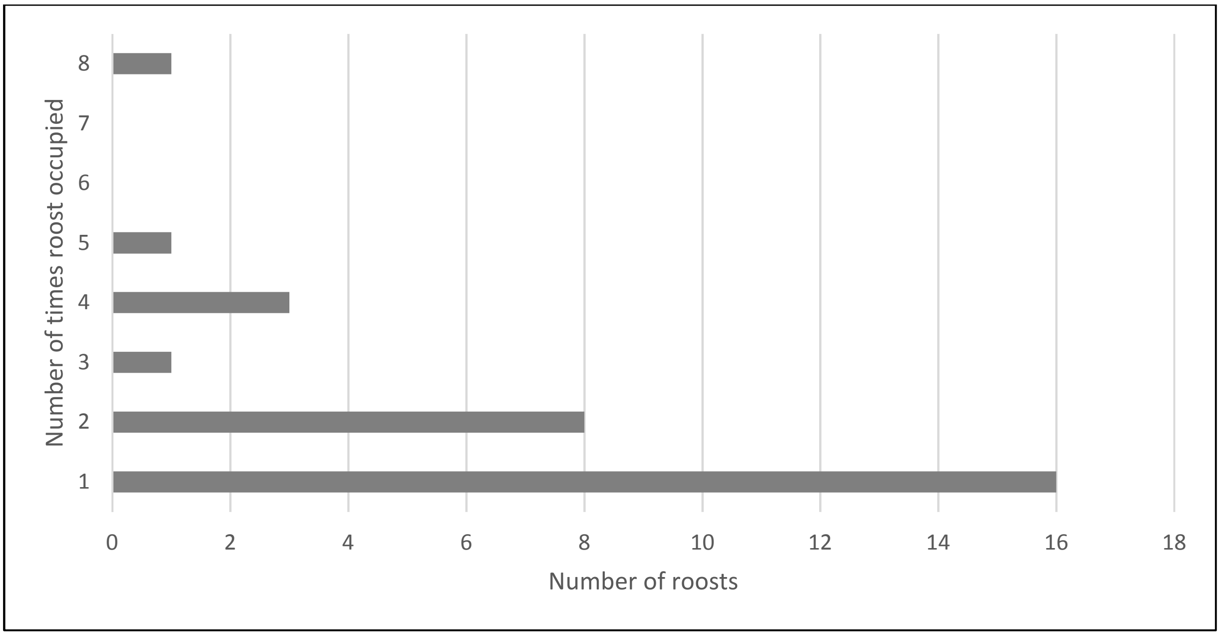


Figure 5: Number of occasions that a roost was occupied during the study (total 24 survey occasions).

Photographs

Figure 6: Brown long-eared bat/s present in R30, note leopard slug *Limax maximus* on photo at bottom left.

Figure 7: R22 10 brown long-eared bats present in photo to left (although unclear in photo), Natterer's bat on right (present on seven occasions in same roost).

Figure 8: R4 Brown long-eared bat roost in fluting (photo on right taken by Michael Walker).

Figure 8: Natterer's bat present within R27.

Figure 9: Natterer's bat present within R26.

Figure 10: Six soprano pipistrelles recorded in R17 in January 2018, with four recorded in February 2018.

Summary

Almost a third (32%) of the 73 trees surveyed were found to support a bat roost, with a total of 30 bat roosts identified within 23 of the trees. Roosts were recorded within 26 flutes, three welds and a hazard beam.

Species recorded

This study has demonstrated that yew trees provide regular roosting habitat for Britain's two most common woodland specialists, the brown long-eared bat and Natterer's bat, as well as occasional roosting habitat for common and soprano pipistrelle. Along with additional records from the BTHK Database (Andrews, 2018), six species of bat have now been confirmed to roost within yew trees; including the four species recorded by this study, together with Leisler's bat and barbastelle.

As may be expected, brown long-eared bat was by far the most recorded species during the study being recorded within 21 of the roosts on 38 occasions. In comparison, Natterer's bat was recorded within five of the roosts and common pipistrelle and soprano pipistrelle were recorded in four of the roosts each.

Seasonal use

Brown long-eared bat and Natterer's bat were absent from roosts during the main maternity period of June to August in both years. Only a single common pipistrelle and soprano pipistrelle roost were recorded during this period. Considering that bats were recorded roosting in-situ on a total of 60 occasions, only 3.3% of records were recorded between June to August. The features within yews are considered to be of low value for maternity roosts, both due to the relatively limited size, exposure of the features and the tendency of features to be at a low height. Based on these results, it is considered that there is limited value in surveying yew trees between June to August.

The results demonstrate that March, April and May comprise the most productive periods to search for bats in yew trees, with an average of four or more roosts recorded per month during this period. An average of two to three and a half bat roosts were recorded per month from September to February over the course of study.

Area

The study found a marked increase in the percentage of trees with roosting bats in proximity to water; 75% of trees within Area 3 were found to support a roost, with 22% and 29% of trees found to support a roost in Area 1 and 2 respectively. Findings are consistent with those of Kalcounis-Ruppell *et al*. (2005), finding an increased use of PRF within proximity to water.

New roosts and rate of occupancy

The rate of occupancy and number of new roosts recorded throughout this study highlight a general pattern of roost switching behaviour on an at least a monthly basis; 53% of the roosts recorded were occupied only once during the 24 surveys and 80% of roosts were occupied on a maximum of two occasions. These results support the findings of studies on roost switching behaviour (Russo *et al.*, 2005; Dietz and Pir, 2009), finding small roosts and individual roosts to exhibit high roost switching behaviour, similar to that recorded by maternity roosts (Russo *et al.,* 2005; Dietz and Pir, 2009; Bohnenstengel, 2012; Kühnert *et al.*, 2016).

Acknowledgements

With thanks to Clumber Park Rangers, Dan Booth and Tom Biddulph, who allowed me to tag the 73 surveyed trees (and even provided the tags) which made the accuracy of this project possible. I would also like to thank members of South Yorkshire and Nottinghamshire Bat Groups for helping out on some of the surveys. Finally, I would like to thank Robert Bell, Greg Slack and Henry Andrews for their encouragement and input throughout the study.

References

Andrews, H. *et al.* (2016) Bat Tree Habitat Key (3rd Edition). AEcol, Bridgwater.

Andrews, H. (2018) Bat Tree Habitat Key 2007-Feb 2018 Database, available from http://battreehabitatkey.co.uk/?page_id=18 accessed 14/02/2018.

Bat Conservation Trust (undated). Woodland Specialists, available from http://www.bats.org.uk/pages/woodland_specialists.html accessed 27/02/2018.

Bohnenstengel, T. (2012) Roost selection by the forest-dwelling bat *Myotis bechsteinii* (Mammalia: Chiroptera): Implications for its conservation in managed woodlands. Bulletin de la Société Neuchâteloise des Sciences Naturelles. 132: 47-62.

Dietz, M. & Pir, J. (2009) Distribution and habitat selection of *Myotis bechsteinii* in Luxembourg: implications for forest management and conservation. Folia Zool. 58(3): 327-340.

Dietz, C. & Kiefer, A. (2016) Bats of Britain and Europe. Bloomsbury, London.

Harris, S. & Yalden, D. (eds.) (2008) Mammals of the British Isles: Handbook, 4th Edition. The Mammal Society, London.

Kalcounis-Ruppell, M., Psyllakis, J. & Brigham, R. (2005) Tree roost selection by bats: an empirical synthesis using meta-analysis. Wildlife Society Bulletin. 33(3): 1123-1132.

Kühnert, E., Schönbächler, C., Arlettaz, R. & Christe, P. (2016) Roost selection and switching in two forest-dwelling bats: implications for forest management. European Journal of Wildlife Research. 62(4): 497-500.

Natural England (1999) Clumber Park SSSI Citation, available from https://designatedsites.naturalengland.org.uk/PDFsForWeb/Citation/1000664.pdf accessed 14/02/2018.

Nottinghamshire Bat Group (2018) Brown Long-eared, available from http://nottsbatgroup.org.uk/bats-in-nottingham/brown-long-eared/ accessed 27/02/2018.

Ordinance Survey Maps https://osmaps.ordanacesurvey.co.uk accessed February 2018.

Russo, D., Cistrone, L. & Jones, G. (2005) Spatial and temporal patterns of roost use by tree-dwelling barbastelle bats *Barbastella barbastellus*. Ecography. 22: 769-776.

Thomas, P. & Polwart, A. (2003) *Taxus baccata* L. Journal of Ecology. 91: 489-524.

Correlates of swarming activity and associated mass mortality among common pipistrelles at Durham Cathedral.

Christopher Paul Bell cp_bell@btintenet.com

Abstract

1. Passive monitoring of bat activity within a common pipistrelle *Pipistrellus pipistrellus* swarming site and hibernaculum at Durham Cathedral cloister was carried out between July and December 2017 and post-mortem examination was performed on a sample of bats found dead or dying during the late summer/early autumn 2017 swarming period.
2. High levels of activity were recorded from late July to early October, with a daily peak of activity recorded in the period after sunset, probably reflecting activity of bats emerging from roosting sites within the cloister. The seasonal trend peaked in late August coincident with persistent day flying and a secondary peak occurred in late September.
3. Greater activity was associated with warmer daytime temperatures and lower overnight wind speeds, especially activity in the middle of the night which was also reduced by rainfall in relatively windy conditions.
4. 210 instances of grounding featuring mostly juvenile bats were recorded within the cloister between July and October. Of these, 143 were followed by rehabilitation and release, while the remaining 63 involved bats found dead or which died in captivity. Although grounded bats were generally under-weight, no evidence of disease was discovered in 12 individuals subject to post-mortem examination and while lead concentration was found to be elevated in kidney tissues this was only to sub-clinical levels.
5. Daily frequency of grounded bats was negatively associated with both activity and temperature the previous night, suggesting that groundings are more likely following nights with poor foraging conditions. However, groundings are also positively associated with the volume of contemporaneous daytime activity.
6. The results are consistent with the hypothesis that groundings occur among juvenile bats that suffer energy deficits because their inexperience leads to inefficient foraging. From a demographic perspective this should apply only to a small proportion of juveniles, which would imply that large numbers of bats must visit the site to account for the number grounded.
7. Morbidity related to disease or ingestion of toxins cannot be entirely ruled out, however, since this would require a more intensive regime of post-mortem examination, especially of fresh tissue.
8. Evidence also suggests the possibility that a persistent late September spike in activity within common pipistrelle swarming sites may represent re-immigration to hibernacula prior to entering extended periods of torpor during October. However, contrary to previous findings there was no indication of immigration to the hibernaculum coincident with the advent of sub-zero temperatures late in the year.
9. Further insight into the significance of swarming and associated groundings could be obtained by radio-tracking the movements of rehabilitated individuals, surveying of numbers roosting within the cloister during swarming, use of thermal imaging and long-term continuous passive monitoring of bat activity at the site.

Introduction

Recent research into the significance of swarming behaviour in common pipistrelle has begun to clarify aspects of the species' biology that were previously poorly understood. Hibernation behaviour in particular has been relatively little known, since the species is uncommon at well-studied underground sites (Harris & Yalden, 2008; von Schaik *et al.*, 2015) and the small numbers of hibernating common pipistrelles discovered each winter has failed to reflect their abundance relative to other species (Korsten *et al.*, 2016). However the results of an intensive study of a mass hibernaculum in Germany (Sendor, 2002) have stimulated further investigations, revealing widespread use of mass hibernacula in the urban environment (Korsten *et al*., 2015).

The success of such investigations suggests the generality of Sendor's (2002) findings regarding the relationship between late summer/early autumn swarming and hibernation. The predominance of females and juveniles during the swarming period supports the 'maternal guidance' hypothesis, whereby swarming emerges from visits to prospective hibernation sites by post-breeding females accompanied by offspring of the year, which thereby learn their locations. After swarming dies down towards the end of September, bats are thought to be absent for several weeks before beginning to re-enter hibernacula around the time of the first frosts in late November or December (Racey, 1973). From this point onwards there is a dynamic equilibrium of numbers, with immigration exceeding emigration during cold periods and vice-versa during warm periods until vacation of hibernacula in the spring (Sendor *et al*., 2000; Sendor, 2002 Appendix B).

The generality of these findings is also supported by similar observations made at Durham Cathedral (Bell, 2016), where common pipistrelle swarming and hibernation occur within the cathedral cloister (Figure 1). However this is also the site of mass groundings and mortality of bats during the swarming period for which there is no obvious cause, although Bell (2016) speculated that it might simply reflect a normal level of post-fledging mortality if the numbers visiting the cloister are sufficiently large. If so, the site may be highly significant for regional populations of common pipistrelles, but if smaller numbers are present the mortality may be regarded as unusual and requiring explanation.

Either way, the situation demands further investigation and Durham Bat Group (DBG) has therefore resolved to initiate a long-term study of the year-round use of the Durham Cathedral cloister by common pipistrelles. From July 2017 continuous monitoring of bat activity in the cloister has been carried out using a remote logger and during the 2017 swarming period a number of the casualties recovered from the cloister by DBG volunteers were sent for autopsy to investigate possible causes of mortality. The results of the latter and an analysis of monitoring data up to December 2017 are presented here.

Figure 1: View from south east corner of Durham Cathedral cloister towards the western towers.

Method

Monitoring of bat activity

Continuous (24-hour) monitoring of bat activity was carried out using an Anabat Roost Logger installed within the cloister. This records ultrasound in zero-crossing format using a microphone with a sensitivity peak at 42Khz. Sounds resembling bat calls are then extracted in the form of files suitable for analysis by Analook software. A single bat-like call generates a file containing all sounds recorded during a minimum period of five seconds (by default) starting immediately before the call. If additional bat-like calls are recorded within this period it is extended for a further five seconds up to a maximum of 15 seconds. Each file can therefore contain anything between a single bat call and multiple complete bat passes.

The number of files generated in each hourly period was used as an index of bat activity, which if continuous would generate an index of 240 (one hour = 240 x 15 seconds), while a single bat call every five seconds would generate an index of 720 (one hour = 720 x 5 seconds). Either estimate may therefore represent the presence of anything from a single bat to several hundred, so the index provides only a crude measure of bat activity and the number of bats present. However, the swarming behaviour at the cloister has long been observed to involve repeated circuits of the cloister ranges (Bell, 2016), in the context of which the frequency of sound file generation by a passive logger may provide an economical method of indexing activity over a long period.

Data analysis was performed using R version 3.1.2. (R Core Team, 2014), with plots generated using the 'Akima' and 'plot3D' packages. Analyses of bat activity and frequency of bat groundings were performed in all instances using quasipoisson errors and a log link function. Data for local variation in sunrise and sunset and of weather variables were obtained from www.timeanddate.com.

Cloister inspections

The cloister was searched on a near-daily basis for grounded bats between late July and mid-October. Because the searches were carried out by several volunteers on a rota basis, they were not performed in a systematic fashion. Timing of searches varied, as did the degree of liaison with various cathedral staff who recovered grounded bats for collection by bat group volunteers. Numbers of bats recovered on a particular date cannot therefore be regarded as an exact or consistent measure of the number of bats grounded on that date, but may reflect daily variation to an extent that rewards analysis in relation to potential causal variables

.

Post-mortems

Grounded bats that were discovered alive during cloister searches were taken into captivity for rehabilitation and release. However, a proportion of the bats found had already died prior to discovery and some of those recovered alive subsequently died in captivity. A sample of these casualties was prepared and transported to APHA laboratories in Exeter for post mortem examination. Corpses were preserved in 10% neutral buffered formalin solution immediately after discovery or the death of a captive bat, with a dorsal incision made to ensure fixation of the internal organs prior to sectioning for histological staining.

Results

Diurnal and seasonal variation in activity

Bat activity within the cloister was recorded continuously from 19/07-31/12/2017 and the results are illustrated in Figure 2.

Substantial activity occurred from the beginning of this period until early October, with a marked peak closely following sunset both in the sense of daily chronology and seasonal variation. Sunset varied between 21:29BST on 19/07/2017 and 18:41BST on 01/10/2017 and throughout this period maximal activity followed within one to two hours. This produced a peak daily activity index exceeding 100 per hour for much of the period, with activity continuing at over 50 per hour for about five hours after sunset before gradually declining towards sunrise. When peak activity exceeded 150, activity levels in excess of 50 per hour continued almost until sunrise.

Substantial day-time flying occurred during August and September and in the second half of August some bat activity occurred throughout most of the day, with the exception of the three to five hour period before mid-day. Activity declined rapidly from the beginning of October and did not exceed a handful of recorded bat passes per night during November and December, with no recorded activity on the majority of nights.

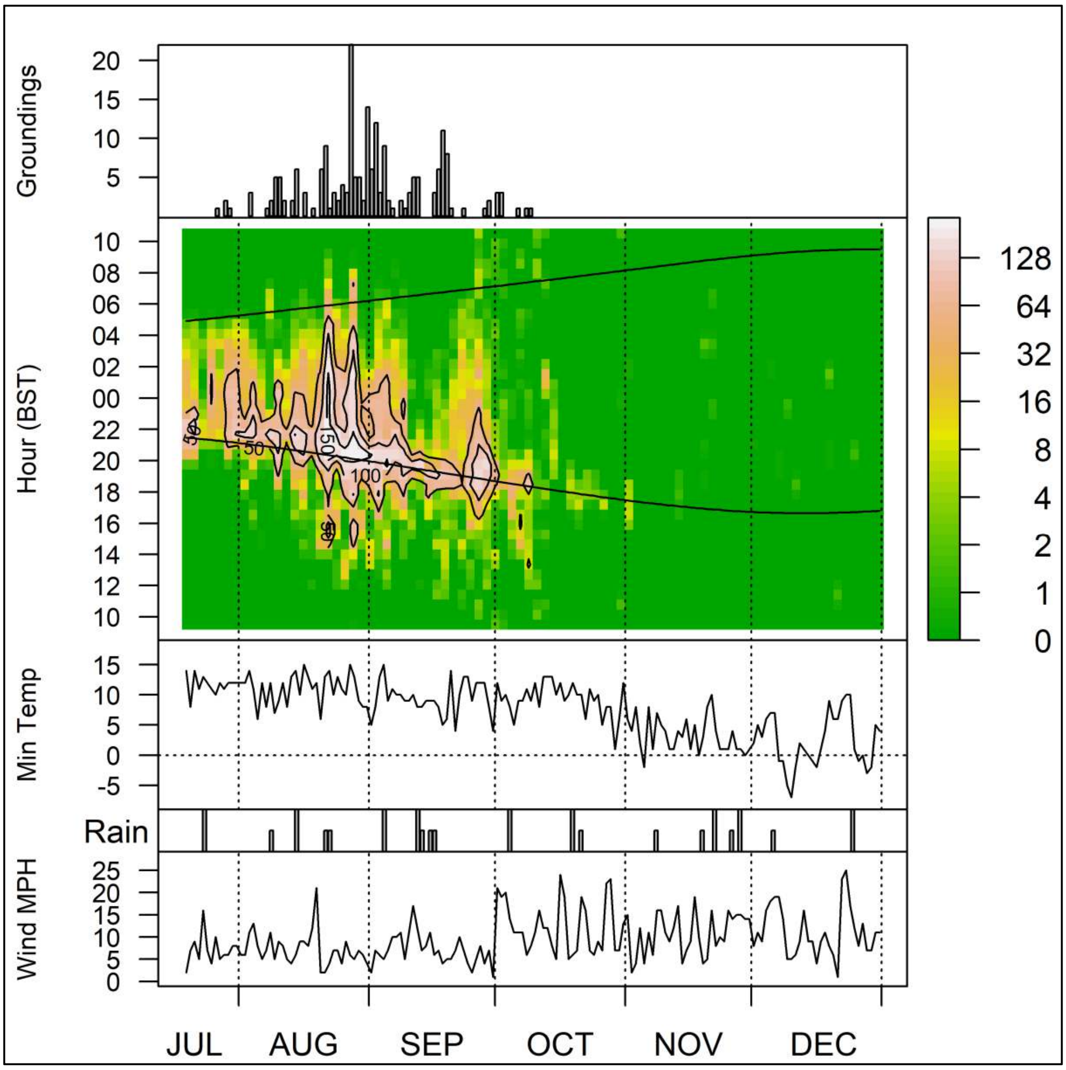


Figure 2: Topographic plot of bat activity at Durham Cathedral cloister in relation to weather conditions and number of grounded bats per day. Contours show the index of bat activity (sound files generated per hour) on a linear scale and colours on a geometric scale to disclose low levels of activity. Curved lines indicate the seasonal trend in sunrise and sunset. All diurnal indices are shown in relation to British Summer Time (GMT+1). The rain chart indicates the occurrence of overnight rainfall either before or after midnight only (short bar) or both before and after midnight (tall bar). The temperature plot shows overnight minima, and the wind plot shows the higher of the average wind speeds recorded between 1800-2400 and 0000-0600 hours.

Correlates of activity

Daily patterns of variation in bat activity indices at the cloister suggest that these may be usefully broken down into successive stages with varying behavioural and functional significance. Correlates of variation in cumulative diurnal activity during the main swarming period between 25/07-31/10/2017 inclusive (81 days), were therefore analysed separately for (i) Daytime: i.e. the period between sunrise and sunset, (ii) Post-sunset, i.e. the two hour period after sunset when peak activity occurs, and (iii) Mid-night, i.e. the period between two hours after sunset and sunrise (Table 1). In each case the candidate explanatory variables included a cubic function of date to account for any underlying trend, a three-way interaction of daily maximum temperature, overnight wind speed and rainfall and a count of the number of rehabilitated bats released each day at the cathedral.

The results for all three indices demonstrate a positive effect of daily maximum temperature, which proved more predictive than both temperature at sunset and the previous night's minimum and a negative effect of wind in addition to an underlying quadratic trend. However the variables proved to have the greatest explanatory power in relation to activity during the mid-night period, for which the negative effect of wind speed showed a significant interaction with rainfall. Data for dates with overnight rain were relatively scarce (Figure 2) but suggest that mid-night activity declined more gradually with increased average wind speed on dry nights than on nights with rain (Figure 3).

The sums of fitted values for the models of daytime, post-sunset and mid-night activity account for 77% of the deviance in cumulative daily activity (null deviance = 25109, residual deviance = 5696) and explains much of the wide variation in activity levels from day to day, apart from exceptionally high levels that occurred from late September onwards (Figure 4).

Table 1: Analysis of deviance in activity indices in relation to date, weather and numbers of rehabilitated bats released, performed via backward deletion of non-significant variables. Temperature refers to same-day maximum and wind and rain to the previous night (Figure 2).

	Daytime		Post-sunset		Mid-night	
Null deviance	11323 (80df)		5692 (80df)		17537 (80df)	
Residual deviance	4766 (76df)		2304 (76df)		5178 (74df)	
	Effect (SE)	P	Effect (SE)	P	Effect (SE)	P
Date	**0.1336 (0.0223)**	**<0.0000*** **	**0.0544 (0.0100)**	**<0.0000*** **	**0.0499 (0.0163)**	**0.0030** **
Date^2	**-0.0013 (0.0002)**	**<0.0000*** **	**-0.0007 (0.0001)**	**<0.0000*** **	**-0.0007 (0.0002)**	**0.0028** **
Date^3	0.00001 (0.00001)	0.4010	-0.000003 (0.000007)	0.6256	-0.00001 (0.00001)	0.3222
Temperature	**0.2598 (0.0506)**	**<0.0000*** **	**0.1200 (0.0320)**	**0.0003*** **	**0.3321 (0.0535)**	**<0.0000*** **
Wind	**-0.0504 (0.0232)**	**0.0330* **	**-0.0380 (0.0146)**	**0.0113* **	**-0.0690 (0.0282)**	**0.0169* **
Rain	-0.0370 (0.1494)	0.8048	0.0406 (0.0945)	0.6686	**1.0566 (0.4603)**	**0.0245* **
Released	0.0325 (0.0182)	0.0780	-0.0074 (0.0161)	0.6490	0.0086 (0.0233)	0.7122
Temperature x Wind	-0.0225 (0.0117)	0.0582	0.0022 (0.0091)	0.8119	-0.0158 (0.0161)	0.3297
Temperature x Rain	0.0076 (0.1219)	0.9506	0.0645 (0.0788)	0.4159	0.2314 (0.2245)	0.3060
Wind x Rain	0.0510 (0.0397)	0.2032	0.0229 (0.0285)	0.4251	**-0.2049 (0.0889)**	**0.0241* **
Wind x Temperature x Rain	-0.0187 (-0.0239)	0.4359	-0.0116 (0.0181)	0.5252	-0.0288 (0.0609)	0.6382

Grounded bats

Cloister inspections were performed on 57 days during the 81 day period between 25/07-31/10/2017, with only seven days missed during the 51 day period of the highest activity between 07/08-25/09/2017. In total 210 groundings were recorded, of which 143 resulted in rehabilitation and release and 67 featured bats found dead or which subsequently died. Released bats were not marked, so repeat groundings may account for a proportion of the total. Only 201 of the groundings were assigned to their date of discovery for subsequent analysis as nine of the bats found dead were either mummified or partially decomposed and had therefore clearly been dead for some time.

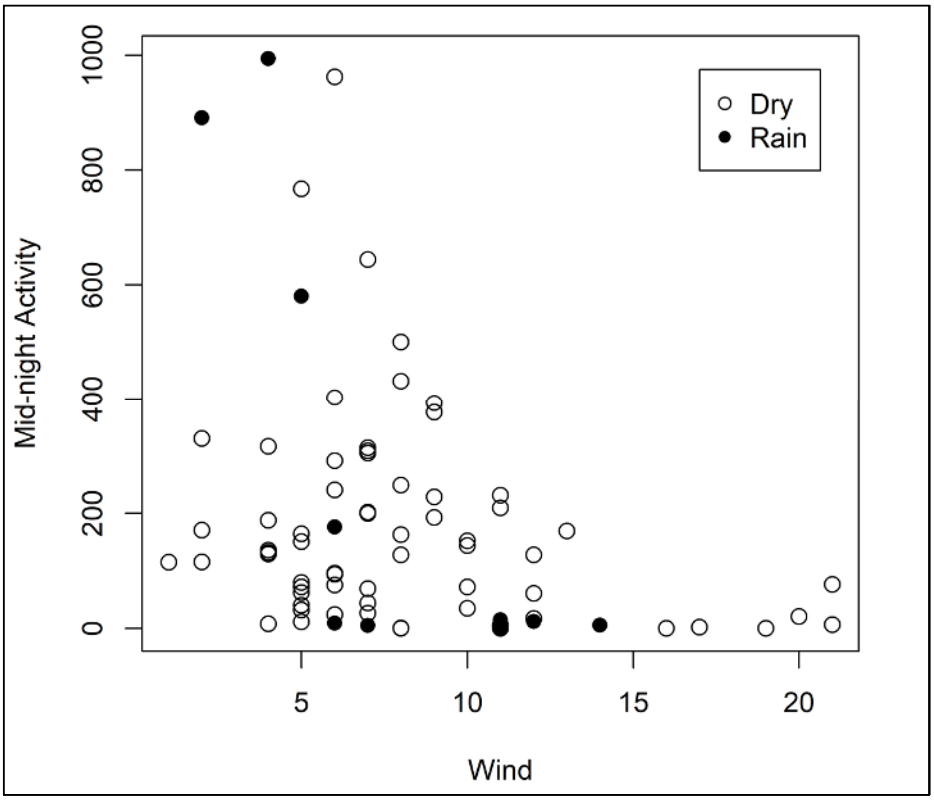


Figure 3: Activity indices during mid-night period in relation to wind speed and rainfall.

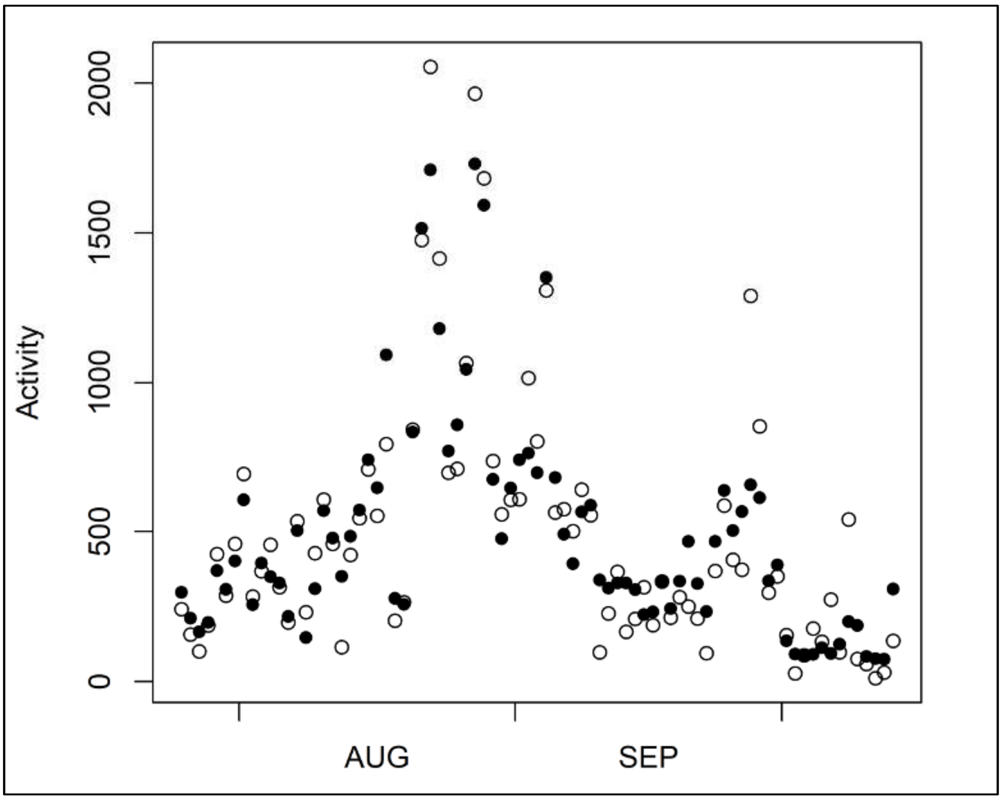


Figure 4: Sums of fitted values for models of daytime, post-sunset and mid-night activity (dots) versus observed cumulative daily activity (circles).

A marked peak in the number of groundings occurred towards the end of August, although as with activity there was much variation in numbers from day to day. The 22 bats recovered on 27/08/2017 far exceeded the next highest daily frequency (14 on 31/08/2017), but only three and five bats were recovered on the preceding and following days, respectively.

Sex, age and weight

Not all the bats located were sexed and aged, but among those that were the sex ratio was even and the vast majority were identified as juveniles (Table 2).

Table 2: Contingency table of sex and age among grounded bats.

	Male	Female	Not sexed	Total
Adult	3	2	0	5
Juvenile	36	35	8	79
Total	39	37	8	84

Weights at discovery of a sample of the bats obtained from the cloister in 2017 are compared in Figure 5 with a sample of juvenile common pipistrelles and soprano pipistrelles *P. pygmaeus* obtained from nearby Hamsterley Forest in August and September 2016, from which it can be seen that the cathedral bats are clearly underweight.

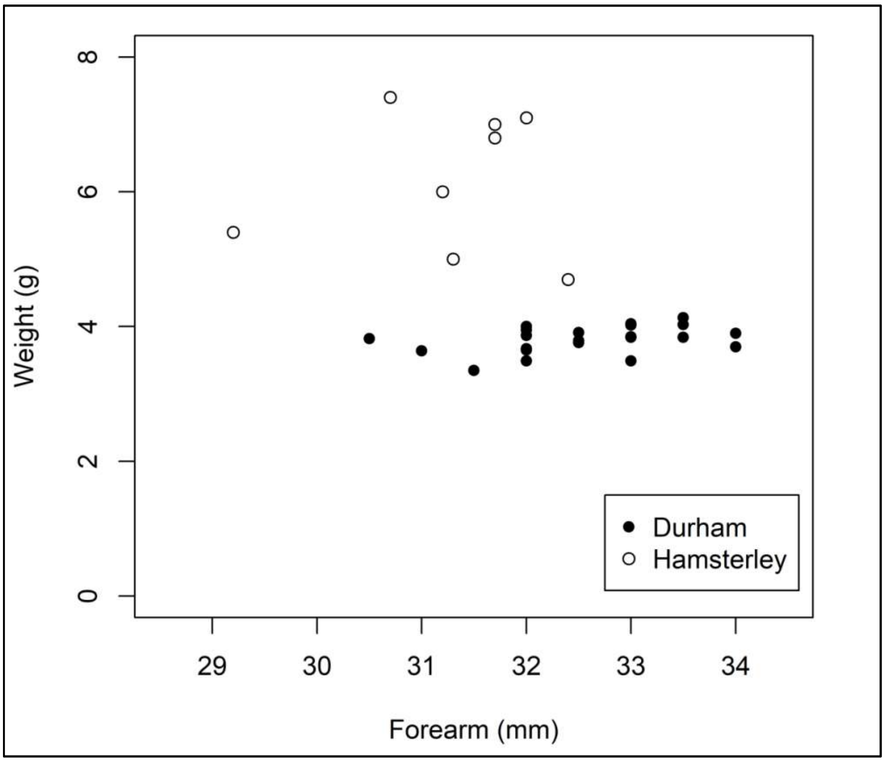


Figure 5: Plot of weight against forearm length of grounded common pipistrelle bats from Durham Cathedral in August/September 2017 and juvenile common and soprano pipistrelles from bat boxes at Hamsterley Forest, County Durham in August/September 2016.

Correlates of grounding frequency

The number of bats located within the cloister on a particular date may have been affected by the fact that cloister inspections were not systematic. Inspections could take place in the morning or afternoon/evening when bats could sometimes be observed becoming grounded immediately after emerging from roost sites at the edges of the wooden beamed range ceilings (Figure 6).

Morning inspections would therefore be likely to miss such groundings, which would not be discovered until the following day. Likewise the numbers on a particular day might include groundings from previous days whenever a gap in inspections occurred. A two-level categorical variable was therefore defined with a value for a given date that varied according to whether inspections occurred before or after midday and an additional three-level variable was defined according to whether inspections had occurred on the previous day either before midday, after midday or not at all. However, neither variable was found to significantly affect the number of groundings recorded (inspections on same day: Δdeviance = 4.6151, $F_{1,51}$ = 2.3682, P = 0.1300; inspections on previous day: Δdeviance = 5.4318, $F_{2,47}$ = 1.4543, P = 0.2439).

Figure 6: North range of the cloister looking east towards the south transept.

Variation in the daily frequency of grounded bats was analysed in relation to a cubic function of date, activity indices for daytime and post-sunset and mid-night periods and the interaction of temperature, wind and rainfall. In addition to an underlying convex quadratic trend, significant deviance was explained by mid-night and daytime activity, but in opposite directions, with a positive effect on frequency of groundings of daytime activity and a negative effect of activity during the previous mid-night period (Table 3a). The model explained half of the null deviance, again including considerable day to day variation, but failed to account for the very high numbers on 27/08/2017, or the flurry of high frequency days in mid-September (Figure 7). No direct effect of weather conditions was detectable independent of activity indices, but when the latter were excluded a significant decline in number of groundings with increased overnight minimum temperature was detectable (Table 3b).

Table 3: Analysis of deviance of daily grounded bat numbers. Wind, rainfall, overnight minimum temperature and mid-night activity indices are for the preceding night, and daytime and post-sunset activity indices for the daytime period to which the count of grounded bats refers. Backward deletion is performed a) with and b) without activity indices.

	Null deviance = 208.98 (56df)			
	a) Residual deviance = 104.00 (52df)		b) Residual deviance = 135.14 (53df)	
	Effect (SE)	P	Effect (SE)	P
Date	**0.0819 (0.0290)**	**0.0067****	**0.1090 (0.0328)**	**0.0016****
Date^2	**-0.0012 (0.0003)**	**0.0016****	**-0.0015 (0.0004)**	**0.0005*****
Date^3	-0.000009 (0.00002)	0.6371	-0.000006 (0.00002)	0.8371
Temp	-0.0500 (0.0432)	0.2524	**-0.1048 (0.0438)**	**0.0202***
Wind	0.0021 (0.0306)	0.9451	0.0227 (0.0304)	0.4580
Rain	0.0008 (0.3201)	0.9981	-0.0118 (0.3203)	0.9707
Daytime	**0.0030 (0.0007)**	**<0.0000*****		
Post-sunset	0.0025 (0.0026)	0.2298		
Mid-night	**-0.0019 (0.0007)**	**0.0006*****		
Temp x Wind	0.0009 (0.0121)	0.9421	0.0128 (0.0126)	0.3168
Temp x Rain	-0.0072 (0.1560)	0.9635	-0.0766 (0.1302)	0.5589
Wind x Rain	0.0756 (0.1039)	0.4706	0.0020 (0.1235)	0.9869
Wind x Temp x Rain	0.0520 (0.0747)	0.4905	0.0285 (0.0796)	0.7224

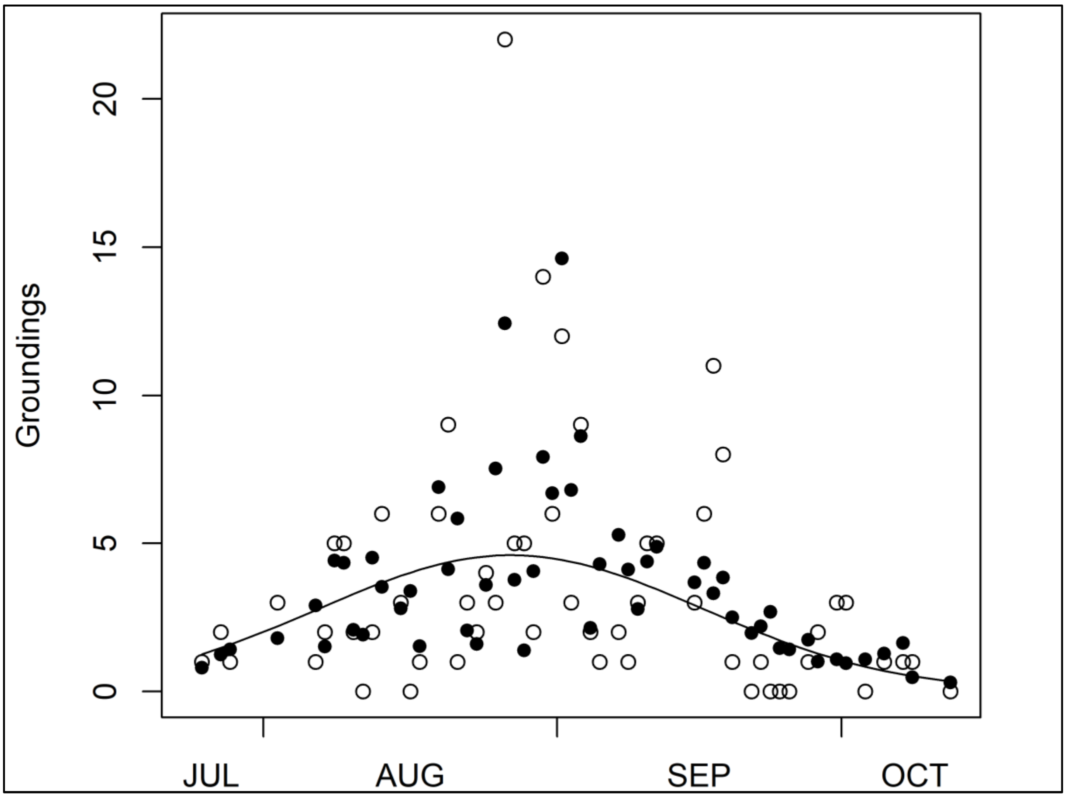


Figure 7: Daily frequency of grounded bats located at the cloister (circles) in relation to fitted values derived from the model in Table 3. The curve shows the significant quadratic trend against date with values for mid-night and daytime activity set at the mean for the period.

Post-mortem results

Post-mortem examinations were carried out on 12 bats recovered from the cloister between 28/07-23/09/2017. Results of the initial histopathology investigation are presented in the appendix.

Some potentially pathological features were seen in the kidney tissues of several of the bats, but no significant findings emerged from further investigation using Periodic acid-Schiff stain, indicating that the features are probably related to immaturity. Sections of the gastro-intestinal tract generally indicated a dearth of ingested material. Further analysis of kidney tissue was carried out for chemical toxin concentration and the results are set out in Table 4. Cadmium concentration is negligible, but there is elevated lead concentration, though not at a level that could be considered clinically significant (Walker *et al.*, 2007). High sodium concentration may be related to the use of formalin fixative.

Table 4: Concentrations of cadmium, lead and sodium in kidney tissues. Sample 1 was taken from 3 of the 6 bats recovered between 28/07-16/08/2017 and Sample 2 from all 6 bats recovered between 30/08-23/09/2017.

	Sample weight (g)	Cd (mg/kg) DWt	Pb (mg/kg) DWt	Na (mg/kg) DWt
Sample 1	0.0167	0.141	15.399	15225
Sample 2	0.0465	0.253	13.522	14497

Discussion

Activity during the swarming period

Roosting within swarming sites

The pattern of bat activity revealed by passive recording within Durham Cathedral cloister highlights a major difference in behaviour from that observed by Sendor (2002) at a comparable swarming site at Marburg Castle in Germany. The latter is not used for roosting during the swarming period, whereas at Durham the peak of activity that consistently occurs just after sunset clearly relates to the emergence of bats roosting within the cloister.

Consequently, the overnight pattern of activity differs from that observed at Marburg, where bats do not begin to enter the site until over two hours after sunset and the volume of activity follows a symmetrical pattern with a peak in the middle of the night (Sendor *et al.*, 2000). During the peak of the swarming season at Durham, activity declines following the post-sunset peak to a plateau extending until after midnight before further decline towards sunrise. Clearly some of this activity must involve bats immigrating into the cloister, since numbers build up through July and August. However, because the entry and exit do not occur through a narrow passage enabling counting using a passive sensor as at Marburg, it is much more challenging to determine the relative contribution to swarming activity of bats roosting at the cloister and those roosting elsewhere.

The reason for the contrast in roosting behaviour between the two sites could conceivably relate to differences in context. At Durham the roosting locations are within and around a 500 year old wooden-beamed ceiling set below a shallow-pitched lead roof that will efficiently conduct radiant heat (Figure 8), whereas the Marburg Castle site comprises a cellar that is open to the outside only through narrow window openings. Since the latter will be substantially buffered from ambient summer warmth, it may be less attractive to newly fledged and still-maturing juvenile bats acclimated to the elevated temperatures that occur within nursery roosts.

Figure 8: View of the cloister from the cathedral's central tower showing the rolled lead sheeting roof over the cloister ranges. Photo by the Revd Peter Barham.

Seasonal trends in swarming activity

Compared to the seasonal pattern of swarming activity observed at the cloister in 2013 (Bell, 2016), there is no indication of a marked peak in activity at the beginning of August followed by a mid-August dip (the presence of which is also suggested in Sendor, 2002 and Sendor *et al.*, 2000), though in both years there is a peak in late August followed by a rapid decline through September. In both Bell (2016) and Sendor *et al.* (2000) there is a suggestion of a short-lived recovery in swarming activity towards the end of September, but this proved to be much more substantial at Durham in 2017 with the seventh highest index of overnight activity occurring on 27/09/2017.

The unusually large late-September peak may have occurred because it followed what appears to be a period of suppressed activity for around 10 days in mid-September (Figure 2), during which practically no activity occurred beyond the post-sunset period. Relatively cool, windy weather during this period may be responsible, commensurate with the general decline of activity detected for all three diurnal time periods with lower temperature and higher wind speeds. A run of days with overnight rainfall during mid-September may also have contributed to the near absence of activity during the mid-night period, for which there is evidence of a negative effect of rain at higher wind speeds.

The failure of the weather-based model to account for the highest levels of activity in late September, despite relatively warm, calm and dry conditions suggests that the late September recovery is real and inadequately modelled by a quadratic temporal trend. If so the occurrence of a late season surge in activity might suggest some re-immigration into swarming sites prior to entry into extended periods of torpor as temperatures decline during October, in which case significant numbers may in fact be present in hibernacula prior to late autumn/early winter immigration.

Effect of the weather on swarming behaviour

Greater activity during warmer, calmer conditions is straightforwardly explained by better feeding conditions created by a greater abundance of flying insects. This might encourage more bats to emerge from roosts, leading to greater post-sunset activity and also free up more time for swarming, leading to greater activity during the mid-night period. If the latter is homologous with the overnight activity observed by Sendor *et al.* (2000), it would primarily involve bats that have journeyed to the swarming site from roosts elsewhere. Deterrence of such journeys on rainy, windy nights might therefore explain the greater predictive power of weather variation in relation to the mid-night period compared to daytime and post-sunset.

It is less straightforward to interpret the effect of wind and temperature on daytime activity, which appears to be confined to the cloister ranges where there are few insects. One possibility is that the bats are flying on relatively warm, calm days to cool down by escaping overheated roosting sites. Speakman (1990) considered this an unlikely explanation for day-flying by common pipistrelles in Britain, but it may be rendered more plausible by thermal environment generated by the lead roofing of the cloister ranges.

Post-swarming activity

The apparent absence of any substantial activity between early October and the end of December is notable in the context of the observations of Racey (1973), Sendor *et al.* (2000) and Korsten *et al.* (2016) suggesting that common pipistrelles vacate swarming sites in early October and then return to hibernate in response to the first frosts of the year. It also contrasts with observations at Durham Cathedral in 2013, which suggested a resumption of activity when overnight temperatures dipped below zero on 19/11/2016 and 22/11/2016 (Bell, 2016) and with remote recording data from the Cathedral in 2010, when several hundred passes were recorded when temperatures dipped below zero on 26-27/11/2010 (Barrett Environmental, 2010).

The Anabat recorders used by Barrett Environmental are designed for use in the open and therefore have a more sensitive microphone setting than the Anabat Roost Logger used in 2017. However, observations in 2013-4 confirm that bats active in winter perform circuits of the cloister ranges and verification procedures carried out in 2017 confirm that bat passes associated with such circuits are recorded by the Roost Logger. On this basis it would seem most likely that there was no influx of bats to the hibernaculum in late 2017 despite the occurrence of several periods of sub-zero night-time temperatures in November and December (Figure 2).

Common pipistrelles are known to visit multiple swarming sites (Sendor, 2002; Korsten *et al.*, 2016), so it may be that bats have adopted an alternative hibernaculum while continuing to visit during the swarming period. Alternatively, bats may have been present but inactive throughout this period, but the fact that no more than a handful of passes was recorded on any night from early October to the end of December (Figure 2) suggests that numbers are small.

Groundings

Mortality rates and foraging efficiency

The very large number of grounded bats that occurred during the swarming period is consistent with findings over a number of years (Bell, 2016) although the figure of 210 probably exaggerates the number involved, as fur-clipping of rehabilitated bats during the 2013 swarming season revealed that repeat groundings were frequent. Nevertheless, the occurrence of such a large number of casualties makes sense only in the context of a rate of mortality somewhere on a gradient between normal levels in a very large population of bats visiting the site and catastrophic mortality on an annual basis in a smaller population which may therefore act as a demographic sink. Determination of where it lies on the gradient must await a reliable estimate of the total numbers of bats visiting the cloister during the swarming season.

Whatever the rate of mortality represented by the numbers involved, the generally emaciated condition of the grounded bats and the apparent lack of gut contents in many of the autopsied individuals, suggests starvation as at least a proximate contributory cause. This is also consistent with the negative relationship between the frequency of groundings and night flying activity, which has been shown to be suppressed during poor weather. High levels of night flying may therefore be taken as proxy of good foraging conditions, during which inefficiently foraging bats are less likely to suffer an energy deficit, which therefore results in fewer groundings. Additional support for a link between groundings and a sub-optimal environment for foraging exists in the form of a negative relationship between the previous night's minimum temperature and the frequency of groundings, since it can be assumed that fewer insects are flying on colder nights.

Environmental factors

The lack of foraging efficiency implied by this evidence may simply be a function of debility related to disease or poisoning by environmental toxins, which would be consistent with an unusually high level of mortality. Observations of bats becoming immediately grounded after emerging from roosting sites could therefore be regarded as significant, as they suggest that grounded bats are primarily those roosting within the cloister, the lead roof of which is a potential source of toxicity. However, post-mortem results indicate a general absence of any signs of disease or clinically significant levels of toxins within the tissues of autopsied bats. Both cadmium and lead were found to be below the critical concentrations expected to cause adverse effects (Cd 105, Pb 25mg/kg dry weight; Walker *et al.*, 2007), although lead concentrations of 13.5 and 15.4 in the two samples are well above the inter-quartile range of a sample of *Pipistrellus* species kidneys from southern England (1.46–4.85), while remaining well below the sample maximum (69.7; Walker *et al.*, 2007). Although this is consistent with contamination related to the roost site, the sub-clinical concentrations suggest that this can be tentatively dismissed as a potential cause of inefficient foraging.

Lack of foraging experience among juveniles

The fact that the vast majority of grounded bats are juveniles suggests that that it might instead relate to inexperience, consistent with the elevated levels of mortality that routinely occur among young animals post-independence. Within this context, the highly significant positive association between day flying and frequency of groundings is notable, since Speakman (1990) speculated that day flying in summer by common pipistrelles is undertaken primarily by juveniles whose inexperience causes inefficient nocturnal foraging, leading to emergence during daylight to make up energy deficits.

At first sight the dearth of insects within the cloister would tend to rule out this theory as an explanation for day flying at the cathedral. However it may be that the bats involved are deterred from venturing beyond the confines of the cloister ranges by the threat of diurnal predators and are engaging in further sub-optimal behaviour commensurate with that leading to the putative energy deficit. On a more speculative level, support for inexperience rather than debility as a cause of inefficient foraging might be inferred from the significant convex quadratic trend in grounding frequency that appears to be independent of the volume of activity within the cloister. The trend rises from near zero in mid-July, peaks at just below five per day in late August, and then declines back to near zero by the end of the swarming period.

In 2013 there was a two week lag between the increase in bat activity within the cloister in early July and the beginning of groundings in mid-July, which might indicate that the beginning of groundings coincides with the appearance of juveniles within the cloister (Bell, 2016). The activity-independent trend in grounding frequency could therefore reflect the proportion of juveniles in the swarming population, though there is no evidence to suggest that this declines from late August onwards. Instead the decline of the activity-independent trend could reflect an improvement in average foraging efficiency among surviving juveniles. Although the evidence for this scenario is currently sparse, it again favours the ‘inexperienced forager’ hypothesis and the observed relationships of grounding frequency suggest no obvious alternative explanation related to disease or contamination.

As in the model of activity, the combination of a quadratic trend and additional significant variables is inadequate to explain the occurrence of a short term uptick, this time comprising a spike of groundings in mid-September (Figure 7). This occurs towards the end of a period of poor weather and relatively low activity (Figure 2) and may therefore reflect the emergence of severely malnourished bats driven to attempt foraging despite the persistence of sub-optimal conditions.

Conclusions and recommendations
The two main candidate theories to explain the mass groundings and mortalities of juvenile bats that occur most years during late summer/early autumn swarming by common pipistrelles at Durham Cathedral cloister are that they either represent an usually high level of mortality caused by an agent such as disease or an environmental toxin, or that they reflect normal post-fledging mortality among juvenile bats related to their inexperience as foragers. Either could cause individuals to forage inefficiently, for which there is evidence in the form of emaciation and lack of gut contents, as well as the greater frequency of groundings during poor foraging conditions. The absence of significant pathology is more consistent with the 'inexperience' hypothesis, but it would be premature to rule out the possible effect of environmental agents. One reason for this is the use of formalin to preserve the specimens, as this might cause leaching of contaminants from tissues. It would therefore be worthwhile to carry out tests for the presence of toxins in fresh tissue samples from fatalities that occur during future swarming periods at the cathedral.

Uncertainty about the numbers of bats visiting the cloister during the swarming period precludes any strong inferences about the causes of groundings and the associated mortality, since knowledge of the rate of mortality within the population is required to assess whether or not it is unusually high. The indices derived from the Roost Logger provide only a relative measure of bat activity and because common pipistrelles generally roost and hibernate in crevices they are difficult to count even in situations with straightforward access. Counting is therefore all but impossible within the 4m high wooden beamed ceiling of the cloister and the shallow pitched roof space above it.

An alternative approach would involve an assessment of the area from which common pipistrelles immigrate into the cloister. This might be achieved via the attachment of miniaturised radio tags to bats grounded within the cloister prior to their release following rehabilitation. If the number of bats visiting the cloister is large, i.e. thousands rather than hundreds, the bats would be expected to immigrate from a relatively wide area and therefore to disperse widely following release. Such an exercise would also provide some indication of the effectiveness of the rehabilitation process.

Some insight might also be achieved through repeated vantage point surveys of the number of bats emerging from roosting sites within the cloister for comparison with activity indices derived from passive recording. Derivation of a general relationship between the number of bats emerging from cloister roosts and the volume of post-sunset activity might enable ballpark estimation of the numbers active at other times of day, though not the number overall nor the relative contribution of locally roosting individuals, for which the rate of turnover would need to be known. One possible method of quantifying movement in and out would be use of a thermal imaging video camera installed in the 66m central tower of the cathedral with a sufficiently wide-angle lens to cover the entire cloister (Figure 8). However this would almost certainly require the floodlights installed in the cloister to be switched off to enable the movements of individual bats to be picked up from such a range.

Reasons for variation in roosting behaviour between swarming sites can only be tested using between-site comparisons, whereby characteristics that vary among sites are associated with differences in roosting behaviour. However the significance of seasonal trends in swarming activity and frequency of groundings can be clarified by long-term monitoring that records activity data over multiple years. Variation in the response to differences in weather conditions between years would clarify the effects of temperature, wind and rainfall enabling quantification of the underlying weather-independent trends using generalised additive modelling, which in turn would provide clues to their provenance. Long-term data will also be required to clarify the status of the site as a hibernaculum through between-year comparison of over-winter activity variation with weather. However, testing of ideas about the relationship between the frequency of groundings and the proportion of juveniles present or their foraging efficiency and about the occurrence of re-immigration prior to entering torpor would require more intrusive methods involving trapping and examination of bats present at different stages of the swarming period.

Acknowledgements

This study was carried out entirely on a voluntary basis by the members of DBG and received no funding other than indirectly from the charitable funds of DBG through use of their Roost Logger. It was facilitated by a wide range of personnel at Durham Cathedral, including Pam Stewart, Ruth Robson, Maya Polenz and the Dean of Durham Andrew Tremlett. Thanks also to Alex Barlow of the Animal and Plant Health Agency and the School of Veterinary Medicine and Science at Nottingham University for performing the post-mortem examinations. DBG volunteers involved in the work were Duncan Elliot, Mike Wilson, Antonio Barbera, Gemma Cone, Bridget Black, Alison Mell and Rachel Hepburn, who recorded data using a methodology devised by Christopher and Gail Cunningham-Brown. Post-mortem examinations were arranged through the good offices of Lisa Worledge of the Bat Conservation Trust.

References

Barrett Environmental Ltd. (2011) Bat Survey Report Durham Cathedral.

Bell, C.P. (2016) Seasonal variation in activity by common pipistrelle bats at Durham Cathedral cloister. Northern Bats Volume 1, available from http://s3.spanglefish.com/s/34944/documents/volume1/durham-cathedral-cloister.pdf

Harris, S. & Yalden, D.W. (eds) (2008) Mammals of the British Isles: Handbook, 4th Edition. The Mammal Society.

Korsten, E., Schillemans, M., Limpens, H. & Jansen, E. (2016) Swarm and Switch: On the trail of the hibernating common pipistrelle. Bat News 110: 8-10.

Racey, P.A. (1973) The time of onset of hibernation in pipistrellle bats, *Pipistrellus pipistrellus*. Journal of Zoology 171: 465-467.

R Core Team (2014) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/

Sendor, T., Kugelschafter, K. & Simon, M. (2000) Seasonal variation of activity patterns at a pipistrelle (*Pipistrellus pipistrellus*) hibernaculum. Myotis 38: 91-109.

Sendor, T. (2002) Population ecology of the pipistrelle bat (*Pipistrellus pipistrellus* Schreber, 1774): the significance of year-round use of hibernacula for life histories. PhD Thesis, University of Marburg. archiv.ub.uni-marburg.de/diss/z2002/0393/pdf/dts.pdf

Speakman, J.R. (1990) The function of daylight flying in British bats. Journal of Zoology 220: 101-113.

Van Schaik, J., Janssen, R., Bosch, T., Haarsma, A.J., Dekker, J. & Kranstauber, B. (2015) Bats swarm where they hibernate: compositional similarity between autumn swarming and winter hibernation assemblages at five underground sites. PLoS ONE 10(7): e0130850. doi:10.1371/journal.pone.0130850

Walker, L.A., Simpson, V.R., Rockett, L., Wienburg, C.L. & Shore, R.F. (2007) Heavy metal contamination in bats in Britain. NERC Centre for Ecology & Hydrology, Monks Wood, Abbots Ripton, Huntingdon, Cambridgeshire, PE28 2LS, United Kingdom, available from http://nora.nerc.ac.uk/id/eprint/633/1/PPWalker_et_al_2007.pdf

Appendix

Results of initial histopathology investigation. All the bats examined were juveniles.

Recovery			Liver	Kidney	Lungs	Heart	Spleen	Stomach	Intestine
28/07/17	Found dead in cloister - rigor mortis, but absent previous day so probably died overnight	♀	There are variable autolytic changes. Some slight dilatation of sinusoids is seen but no significant hepatocyte changes.	Amorphous eosinophilic droplets are seen in dilated Bowman's capsules in many glomeruli.	These are congested with some artefactual collapse.	No significant findings.	Significant autolysis is seen.	This is well preserved but no significant findings.	There is more significant autolysis and only scant contents seen.
29/07/17	Found dead in cloister - some rigor mortis, but obviously trodden on & fresh entrails extruded.	♂	There was no liver section on prepared slide.	There are more localised glomerular changes as seen above. Slightly basophilic flocculent material is seen in many tubules.	These are very congested with artefactual collapse. There is possible slight increase in cellularity but probably an artefact.	No significant findings.	The red pulp is very congested .		This is generally well preserved with prey material seen in lumen. A couple of cross-sections of possible nematodes are seen but with little associated pathology.
03/08/17	Found grounded in cloister. In poor condition, so probably grounded 1 day +. Died in captivity 04/08/2017.	♀	There is variable autolysis but with no significant findings.	There are changes similar to the above.	Again congestion and a degree of artefactual collapse is seen.	No significant findings.	No section.		There is variable autolysis and scant contents.

Recovery			Liver	Kidney	Lungs	Heart	Spleen	Stomach	Intestine
09/08/17	Found dead in cloister - rigor mortis but recent. Forearm 32mm, weight 3.67g	♂	There is slight dilatation of the sinusoids and scattered hepatocyte necrosis/autolysis is seen.	Similar changes as previous cases.	There is variable autolysis, slight congestion but no significant findings	There is variable autolysis but no significant changes.	No significant findings.	There is generally scant contents and a single cross section of a possible helminth is seen.	
09/08/17	Found dead in cloister - rigor mortis but recent. Forearm 33mm, weight 3.84g	♀	There are areas of autolysis but the well preserved parts show no significant findings.	Part is autolysed but the glomeruli are congested with droplets in Bowman's space and flocculent material in many tubules.	There is slight congestion but no significant findings.	No significant findings.	No significant findings.	This is well preserved but little contents seen.	There is variable autolysis and some contents seen.
16/08/17	Found dead in cloister - very fresh. Forearm 33.5mm, weight 4.03g.	♀	This is slightly autolysed but no significant findings.	There is glomerular congestion but very limited capsular distension. Some basophilic droplets are seen in the tubules.	There is variable autolysis but no significant findings.	No significant findings.	No significant findings.		There were areas of extensive autolysis but in better fixed parts no significant findings were seen.

Recovery			Liver	Kidney	Lungs	Heart	Spleen	Stomach	Intestine
30/08/17	Found alive in cloister, died shortly afterwards. Forearm 33mm, weight 4.01g.	♀	Unremarkable.	There is a degree of autolysis. Wispy pale eosinophilic contents in tubules.	These are congested with very limited hyperplasia of bronchiolar epithelium and swelling of arteriolar endothelial cells. There is some artefactual collapse and possibly a limited focal mononuclear increase in cellularity.			Unremarkable except lack of feed contents.	
30/08/17	Found dead in cloister. Forearm 31.5mm, weight 3.35g	♂	Unremarkable.	Pale flocculent material is seen in many glomeruli.	There is moderate congestion and artefactual collapse of alveoli.			There is a moderate degree of autolytic change. Little feed is seen and a cross section of a female possible nematode.	
02/09/17	Found alive in cloister, died shortly afterwards. Forearm 33mm, weight 4.04g.	♂	A degree of autolysis is seen otherwise unremarkable.	No kidney seen on this slide.	These are congested and slightly collapsed.				
09/09/17	Found dead in cloister. Forearm 33mm, weight 3.84g.	♀	Numerous sections but unremarkable except for autolytic changes.	No kidney seen on this slide.	These are congested and slightly collapsed.			Unremarkable.	

Recovery			Liver	Kidney	Lungs	Heart	Spleen	Stomach	Intestine
17/09/17	Found alive in cloister, died shortly afterwards. Forearm 33.5mm, weight 4.13g.	♀	Unremarkable.	Some flocculent material is seen in glomeruli.	These are congested with some artefactual collapse.			A cross section of possible nematode is seen.	
23/09/17	Found dead in cloister. Forearm 31mm, weight 3.64g.	♂	Unremarkable.	Some flocculent material is seen in glomeruli.	These are congested with some artefactual collapse.			A cross section of possible nematode is seen.	

Gibside Hall Hibernaculum.

Helen McDonald helen.mcdonald1@nationaltrust.org.uk

Gibside Hall cellars

Gibside Hall, once the home of the Blakiston and Bowes family at Gibside estate in Gateshead's Derwent Valley, is now a ruin and a Scheduled Ancient Monument. The shell of the building is all that remains, with no roof and much of the internal structure no longer in place. Most of the network of cellar rooms are better preserved and protected from the elements. The main cellar corridor is open at both ends, as well as having several openings where doors and windows once were and so is exposed to wind and light. There are rooms leading off this corridor that are more sheltered, especially those with partitions within the rooms cutting out light and draughts. Another large room with a high ceiling is accessed from a separate entrance and it is also sheltered from wind by a retaining wall.

Figure 1: Gibside Hall main cellar corridor.

Early cellar hibernation surveys 2002-2007

In 2002 and 2003, hibernation surveys were carried out in the cellars and hibernating *Pipistrellus* species bat and brown long-eared bat *Plecotus auritus* were recorded. These species were again found in 2006 and 2007, with Natterer's bat *Myotis nattereri* also being found in January and February 2007.

The hibernating bats used a number of features in the cellars, including crevices and cracks in the brickwork of the vaulted ceilings and masonry of doorways. Some were found hanging openly in more sheltered rooms of the cellar, away from draughty tunnels. There are potentially more suitable spaces for hibernating bats in the cellars, where there are areas of lifting plaster and brickwork but a lot of these places are too high and cannot be reached safely for surveying.

Changing access

Due to its ruinous condition, access to the Hall is restricted. Before 2007 a timber fence surrounded the building, but in 2007 a Heras fence was installed to prevent any human access. This greatly reduced disturbance inside the building from humans, although badgers *Meles meles* were recorded entering and exiting the building at several points. Since 2007 summer emergence surveys of the Hall have had to take place with volunteer surveyors standing outside the fencing, limiting the views of emerging bats.

No further access for hibernation surveys was allowed until an architectural condition survey of the Hall was carried out in 2014. As a result of the findings of this survey, and continually monitoring the movement of the building, a risk assessment for access to the building for hibernation surveys was agreed and hibernation surveys re-started in January 2016.

Recent hibernation surveys 2016-2018

The winter in 2016 was mild. No bats were found in Gibside Hall cellars in hibernation surveys in January and February 2016. Similar results of low numbers or no bats were recorded in other known hibernacula in 2016. Herald moth *Scoliopteryx libatrix* and cave spider *Meta* species were recorded in most rooms of the cellars.

Figure 2: Cave spider in Gibside Hall cellars.

No bats were recorded in 2017, but herald moths were counted.

Continuing the survey effort on 24/01/2018, herald moths were recorded, but this time two hibernating bats were also found. The first was a Daubenton's bat *M. daubentonii* in a deep crack in the ceiling, in the exact same spot where a Natterer's bat was found in 2007, eleven years ago to the day. The other bat was a soprano pipistrelle *Pipistrellus pygmaeus* in the brick work over a doorway, also in the same spot that a *Pipistrellus* species bat was found in February 2007.

ibutton data loggers were left near both bats to record the temperature at four hourly intervals close to their locations and a SM2 bat detector was positioned between the Daubenton's bat and the nearest exit from the cellar.

Figure 3: Daubenton's bat hibernating in Gibside Hall January 2018.

The follow-up survey on 26/02/2018 found both bats had left their roosts. The temperature data close to the Daubenton's bat fluctuated between 3-4ºC from 01/02/2018 dipping to 2.5ºC in the early hours of 12/02/2018. One *Myotis* species bat call was recorded on the SM2 at 21:25:53 on 11/02/2018, possibly the Daubenton's bat on the move?

The Hall cellars have been added to the Bat Conservation Trust's National Bat Monitoring Programme hibernation survey. We will to continue to monitor the cellars as a hibernaculum and this information will help inform future structural work or changes in access arrangements to the building.

Cumberland Bat Recording Project.

Patryk Gruba pat.gruba@gmail.com

Cumbria is home to 10 of 18 resident UK bat species with eight species being confirmed breeding within the county. Most of the landscape within the county is rural with a broad range of habitats including open fells, wooded valleys, extensive wetland areas, estuaries and coastal habitats. Some of these provide excellent habitat for bats to forage, commute and roost.

Although, there are plenty of suitable habitats that are likely to support a range of bat species within the vice-county of Cumberland, the actual records for bats that are held by the Cumbria Biodiversity Data Centre are very scarce. As depicted by the heatmap (Figure 1), the majority of the records are distributed around the main settlements (Carlisle, Keswick, Penrith, Cockermouth and Egremont) with very few records from the rural areas.

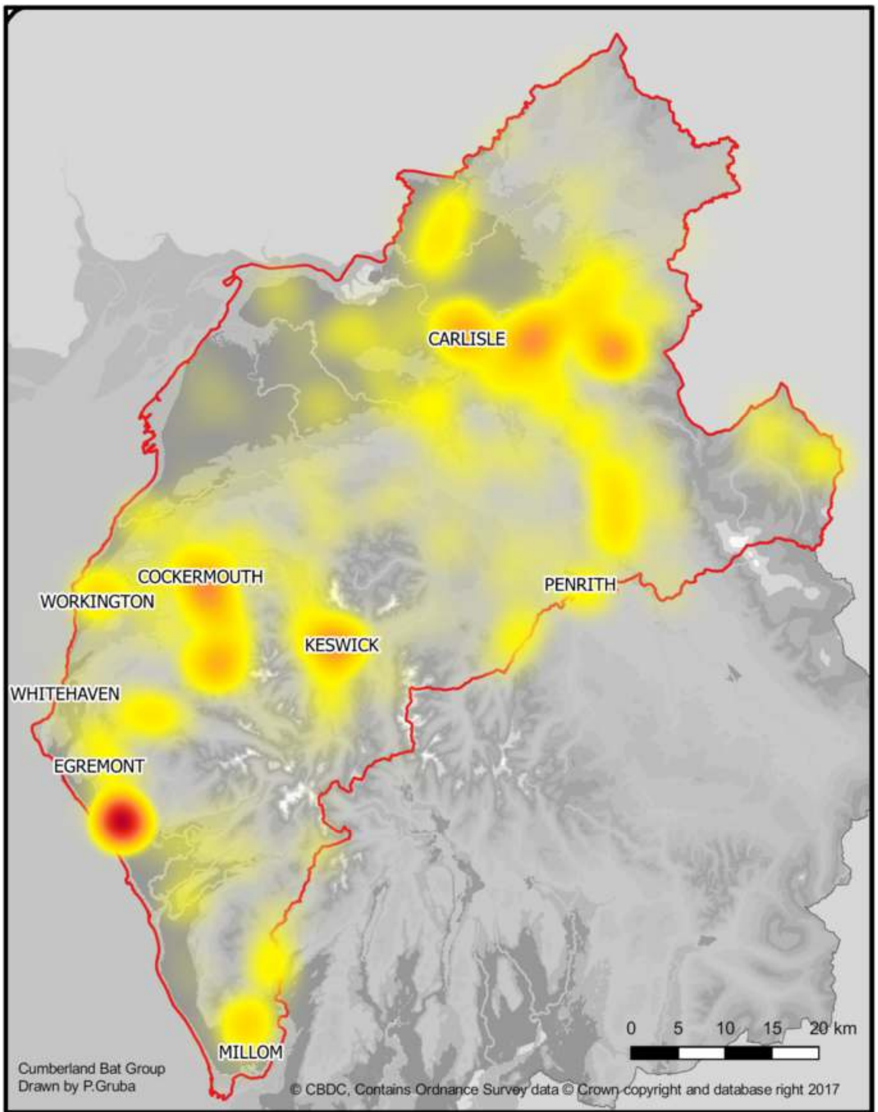


FIGURE 1. HEATMAP SHOWING DISTRIBUTION OF BAT RECORDS WITHIN THE VICE-COUNTY OF CUMBERLAND

RECORDS COURTESY OF CUMBRIA BIODIVERSITY DATA CENTRE (NOV 2016)

As indicated by Figure 1, there are major gaps in the recorded bat distribution (as per November 2016). Therefore, inspired by the Nottinghamshire Bat Group's project "Echo Location Location", the Cumberland Bat Group embarked on the new project to identify the distribution and current status of bats within the vice-county of Cumberland. We hope that the results of the project can eventually aid the production of a "Cumbria Bat Atlas" that can accurately illustrate distribution and range of the bat species that occur within our county.

To aid the recording project, in April 2017, I created a list of tetrads with not a single record for bats; the total number of tetrads with no records accounts for 664 out of 1137 tetrads that cover the Cumberland area (Figure 2 with the red dots depicting tetrads with no records for bats).

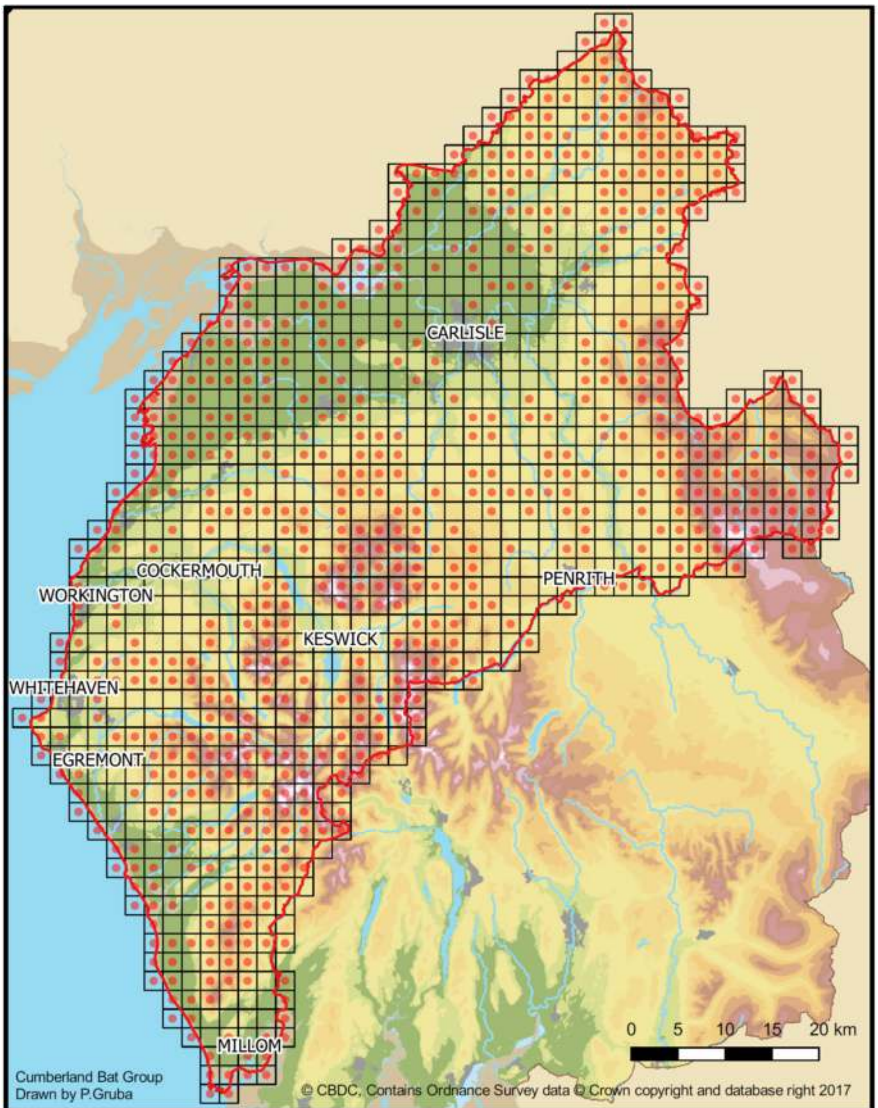


FIGURE 2. TETRADS WITH NO RECORDS FOR BATS (NOV 2016)

VICE-COUNTY OF CUMBERLAND

As seen in Figure 2, there are a lot of tetrads with no records and the attempt to undertake recoding in all of these would be very challenging and might take several years! The blank tetrads cover a range of habitats, from the top of Scafell Pike to wetlands of the Solway Plain and Kielder Forest and all these vary in their suitability for bats. Therefore, to steer the focus towards the tetrads that have the greatest chance of bats being present, all of the tetrads have been categorised by their habitat suitability to the local bat populations (Figure 3).

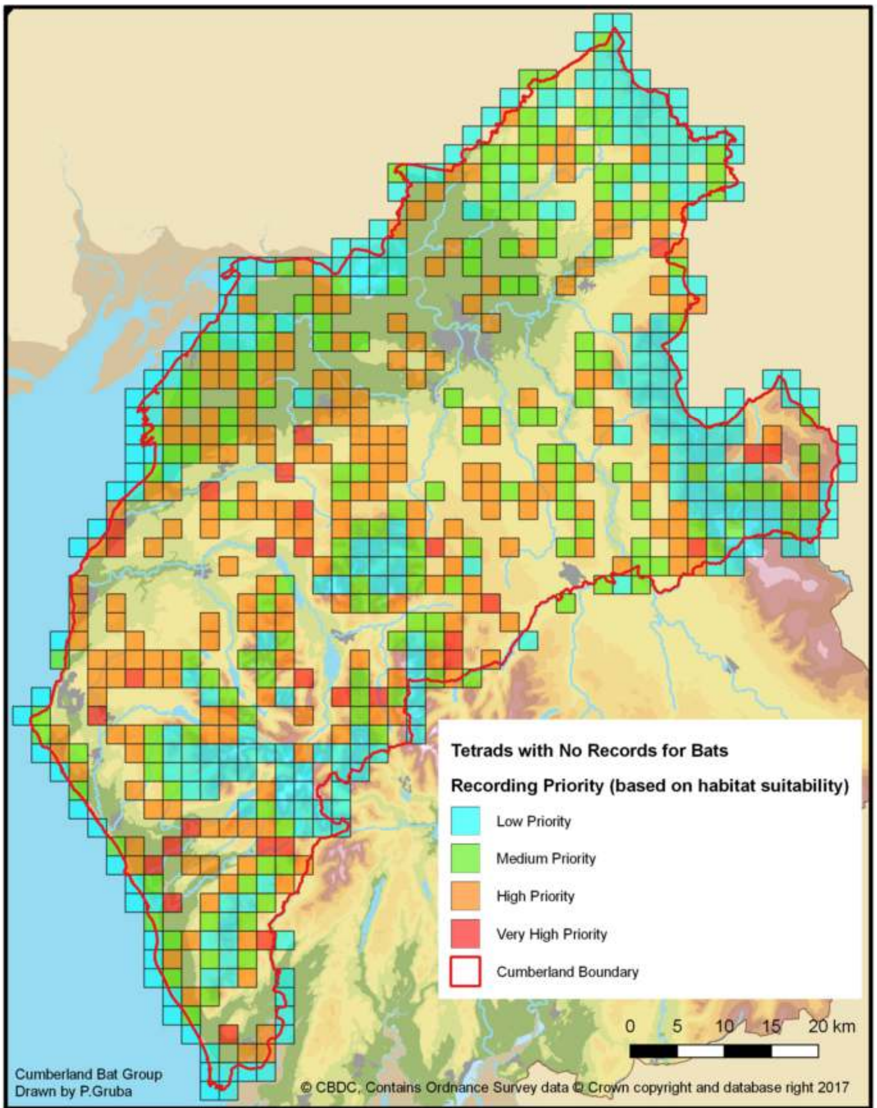


FIGURE 3. TETRADS WITH NO RECORDS FOR BATS (NOV 2016)
RECORDING PRIORITY BASED ON HSI VALUE

VICE-COUNTY OF CUMBERLAND

In order to calculate the habitat suitability, I have taken into account three factors: proximity of woodland (in this case Priority Broadleaved Woodland), proximity of freshwater habitat and proximity of buildings. With the aid of GIS software (specifically QGIS) and readily available spatial data from Natural England Database, Ordinance Survey and Open Street Maps, I have calculated a percentage distribution of the above three factors within each tetrad in order to establish Habitats Suitability Index (HSI) score for an individual tetrad.

To work out the HSI values I have used the following equation (which is similar to the equation generally used by ecologists to evaluate the suitability of habitat for great crested newt *Triturus cristatus*). The HSI is a geometric mean of three factor indices:

$HSI = (F1 \times F2 \times F3)^{1/10}$

- F1 – percentage cover of Priority Broadleaved Woodland (+500m buffer area) within a tetrad (Natural England Database)
- F2 – percentage cover of buildings (+500m buffer area) within a tetrad (Open Street Maps)
- F3 – percentage cover of waterways (+200m buffer area) within a tetrad (Ordinance Survey Open Rivers Data)
- Calculated values are between 1 (minimum) and 100 (maximum)
- All of the 0 values for individual factors have been replaced by 1

Finally, a habitat suitability within each tetrad has been assign into four categories:

- Very high suitability for bats – HSI value equal or greater than 51 (out of maximum value of 100) – 29 tetrads in total
- High suitability for bats – HSI value equal or greater than 16 and lower than 51 – 213 tetrads in total
- Medium suitability for bats – HSI value equal or greater than 6 and lower than 16 – 165 tetrads in total
- Low suitability for bats – HIS value lower than 6 – 257 tetrads in total

I am aware that the method I used is subjective and there may be some drawbacks in the analysis and reasoning; however, I hope it will help with the recording process and target the areas of habitats that are likely to support important bat populations.

In 2017, we had number of records coming in to fill the gaps on the map, but there is still a long way to go. So If you already hold any records for bats from the target tetrads, please submit them directly to Cumbria Biodiversity Data Centre (details can be found on their website), through iRecord or send them to the Cumberland Bat Group.

If any “batty” people would like to help with the project, please get out there after dusk in the bat active season (May till September) and start recording our Cumbrian bats! If you don’t own any detectors, the Cumberland Bat Group has recently purchased an Anabat Express and Echo Meter Touch 2 bat detector so these can be booked and used for the recording. The Cumberland Bat Group will be regularly posting updates on the project on their Facebook page and website.

For anybody that would like to help with the projects, the excel spreadsheet, PDF map and Google Earth (kmz) file showing coordinates and HSI values for all of the target tetrads can be obtained from here:
https://drive.google.com/open?id=1_IgHMMPtL32-YUST51bs3fqufXd0XpLn

Have BatNav, still travelling.

Tina Wiffen malinka1999@btinternet.com

This is an update on the driven transect survey project first published in Volume 1 of Northern Bats (Wiffen, 2016). The methodology has remained the same, an Anabat SD2 with the microphone pointing out of the car window connected to a BatNav GSP logger with bats recorded when driving at less than 40mph. The project is not a systematic survey of bat distribution and does not follow set transects, rather it is opportunistic, recording bats during night time journeys, usually on the way home. The last two years has seen gaps in the data filled and includes forays into Cumbria and North Yorkshire too, with a total of 9984 individual bat records now collected (Figure 1).

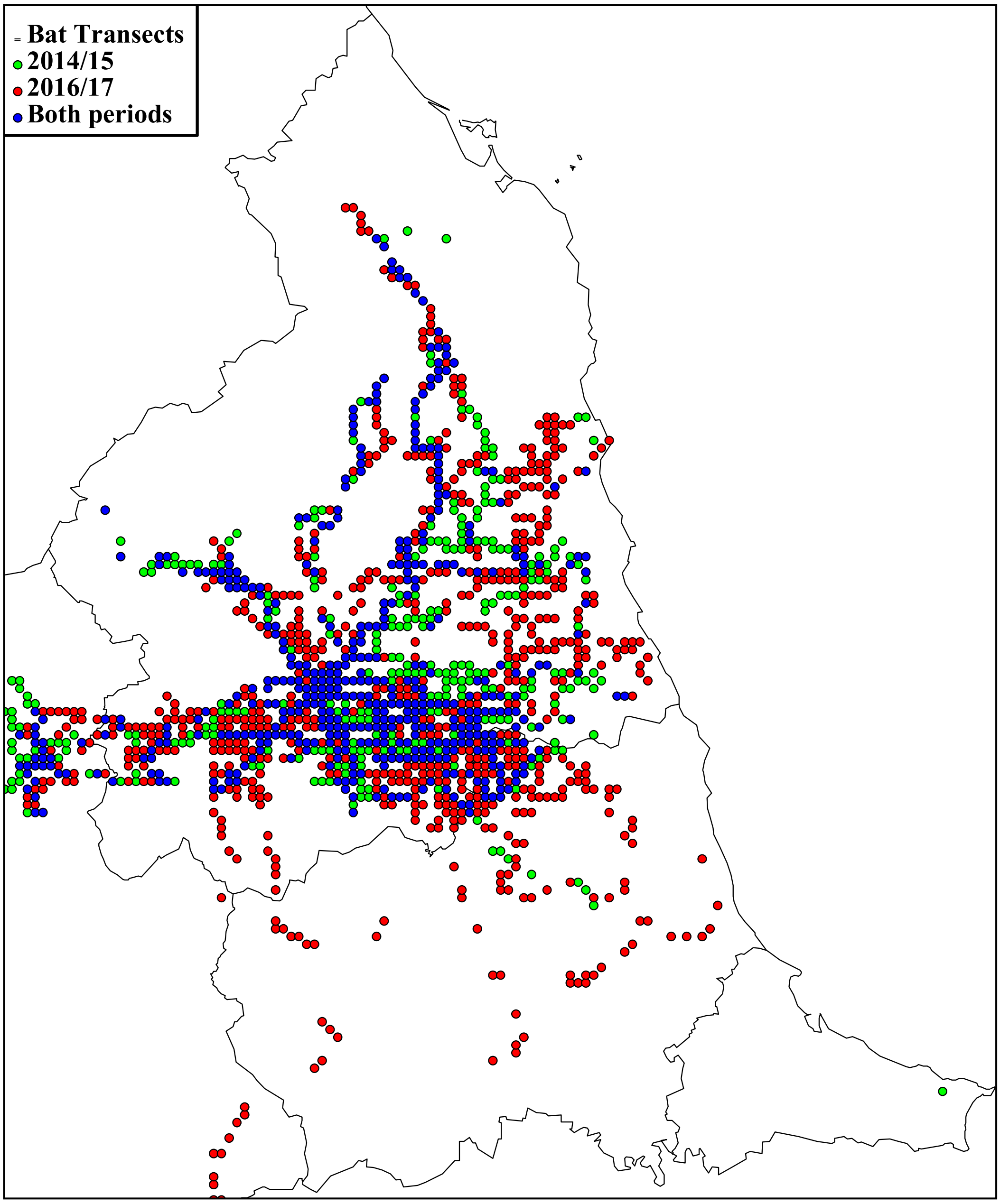


Figure 1: All bat distribution map.

As discussed before the majority of the calls recorded are *Pipistrellus* species bats, 9316 out of the 9984 calls recorded. *Nyctalus* species calls accounted for 2.5% of the calls and 3.6% are *Myotis* species calls. These figures show a close correlation to the data gathered over two years; after two years 2.6% of calls were *Nyctalus* species and 3.7% were *Myotis* species. Nine brown long-eared bat *Plecotus auritus* calls have been recorded over four years, with four in 2014-5. These figures demonstrate that the data collected for individual species/species groups has been consistent over the project.

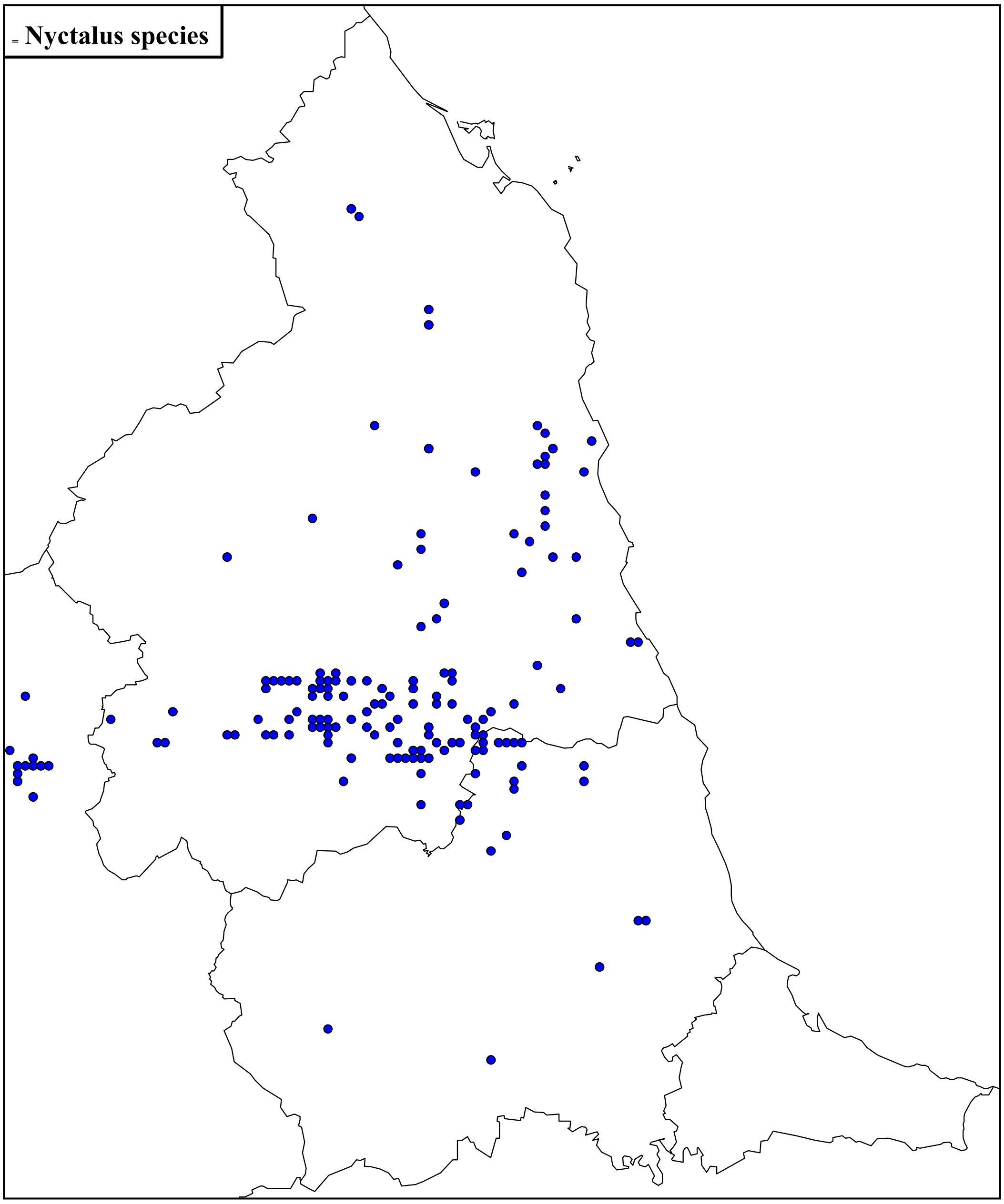


Figure 2: *Nyctalus* species bat distribution map.

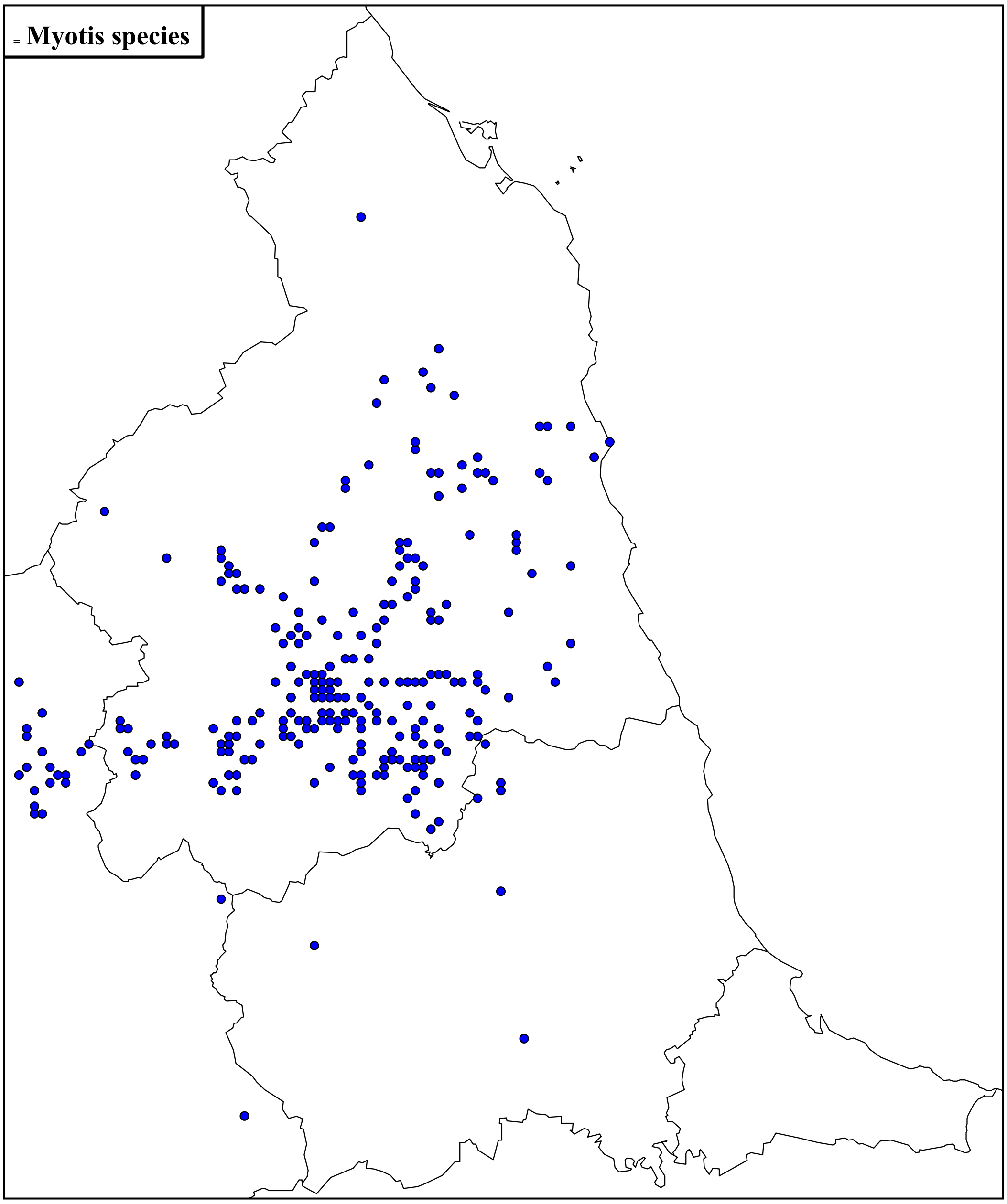


Figure 3: ***Myotis*** **species bat distribution map.**

A study in the Everglades National Park comparing mobile with static acoustic monitoring (Braun de Torrez *et al.*, 2017) found that driven transects underrepresented bat species richness and, in their study, failed to detect three rare bat species which were known to be present. This shows the limits of this technique for producing distribution maps for wider areas but this method does, within these caveats, provide up to date records for wider areas with the minimum of extra survey effort.

This data has been shared with ERIC North East and Cumbria Biodiversity Data Centre, the two local record centres and with Cumberland, Durham, Northumberland and North Yorkshire bat groups. I would be interested to know if anyone else is doing this, gathering data in this way does provide distribution data and if pooled has the potential to create comprehensive maps and up to date bat distribution for the region.

References

Braun de Torrez, E.C., Wallrichs, M.A., Ober, H.K. & McCleery, R.A. (2017) Mobile acoustic transects miss rare bat species: implications of survey method and spatio-temporal sampling for monitoring bats. PeerJ 5:e3940; DOI 10.7717/peerj.3940.

Wiffen, T. (2017) Have BatNav, will travel. Northern Bats. Volume 1, available from http://s3.spanglefish.com/s/34944/documents/volume1/have-bat-nav-will-travel.pdf