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

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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)

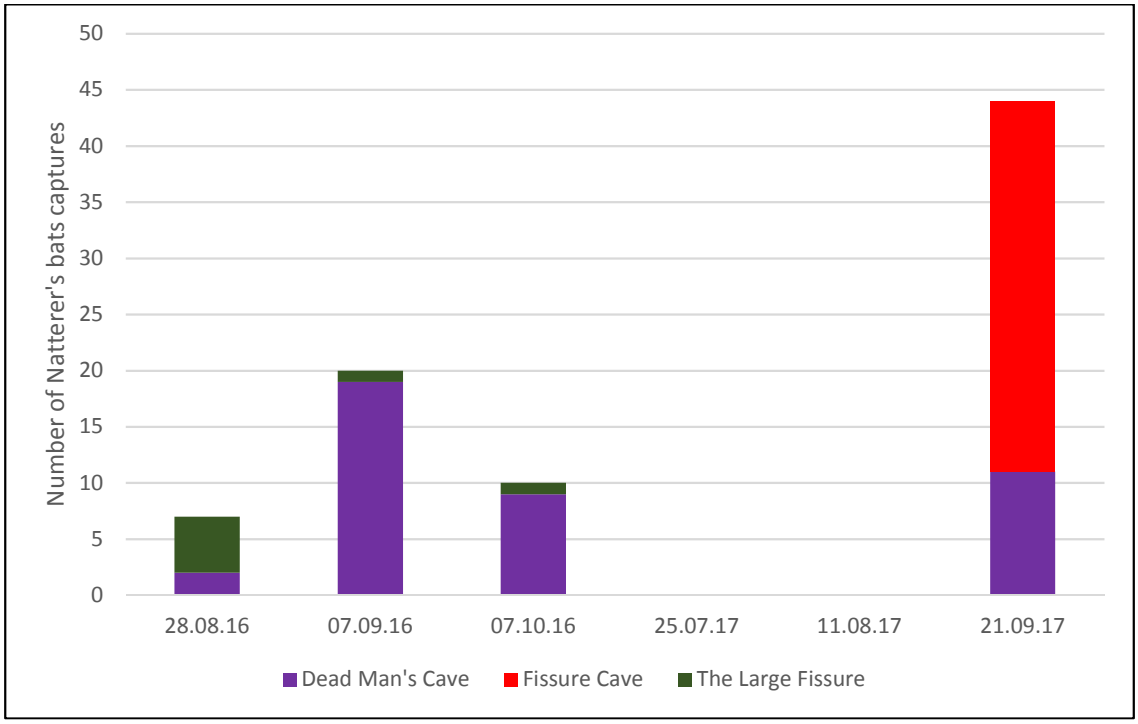

Figure 5: The number of Natterer's bat caught at Dead Man's Cave and Large Fissure in 2016, as compared to the number recorded from Dead Man's Cave and Fissure Cave in 2017.

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.

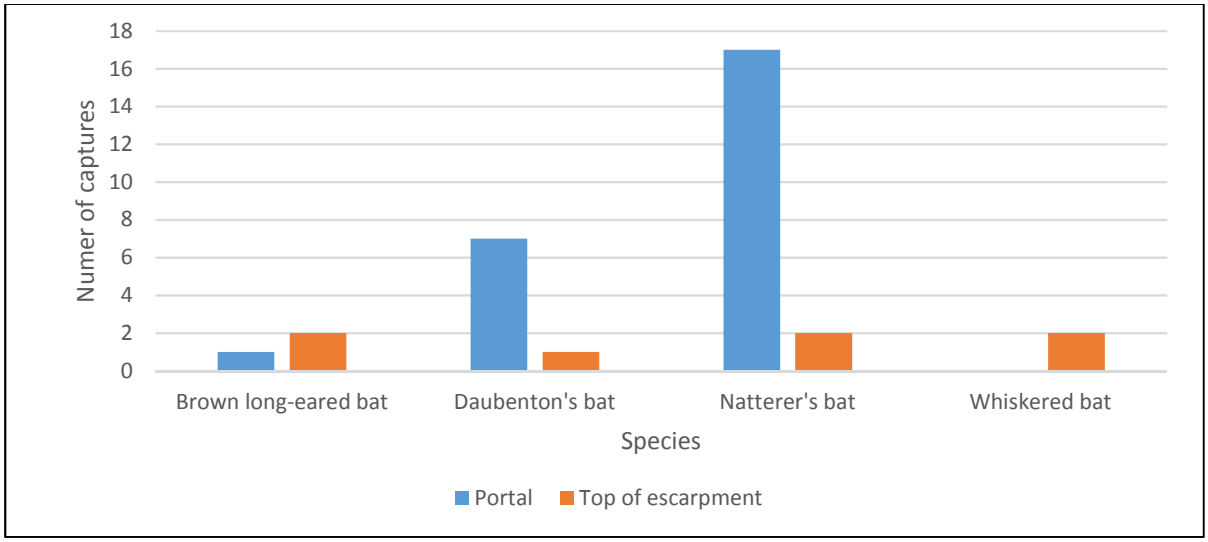

Figure 6: Number and location of bat captures at Cadeby Pot.

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.

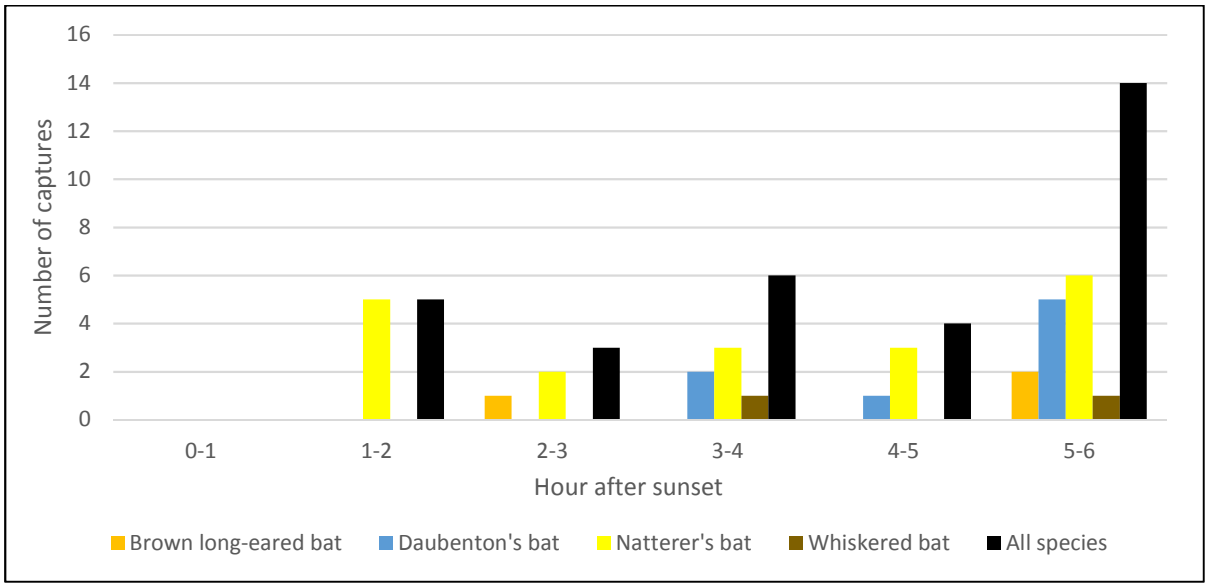

Figure 7: Cadeby Pot captures broken down by time after sunset.

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.

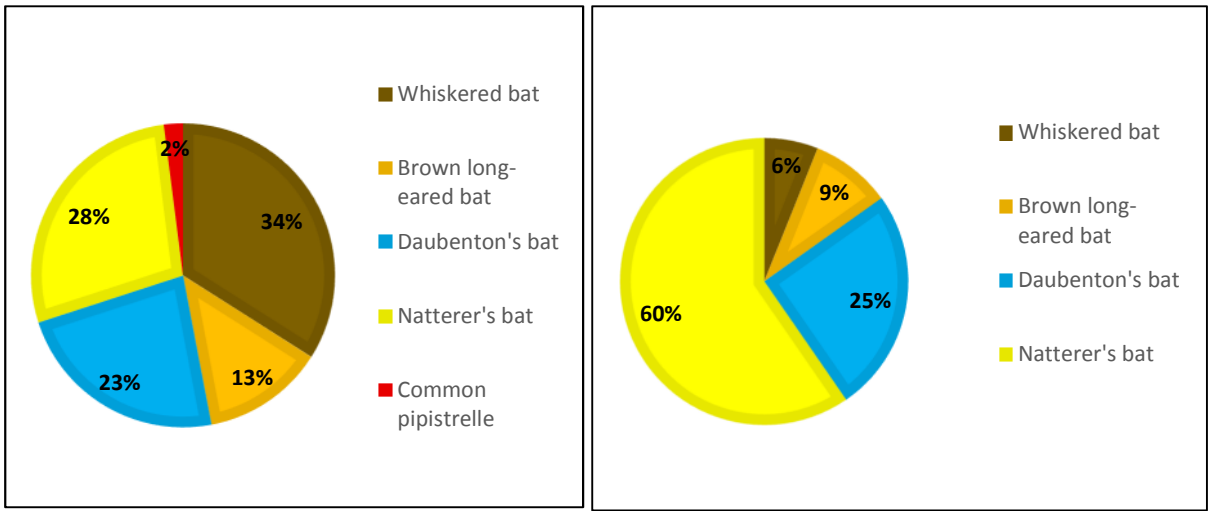

Figure 8: 2016 species composition at Nearcliff Wood Rift (left chart), compared with species composition in 2017 at Cadeby Pot (right chart).

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.

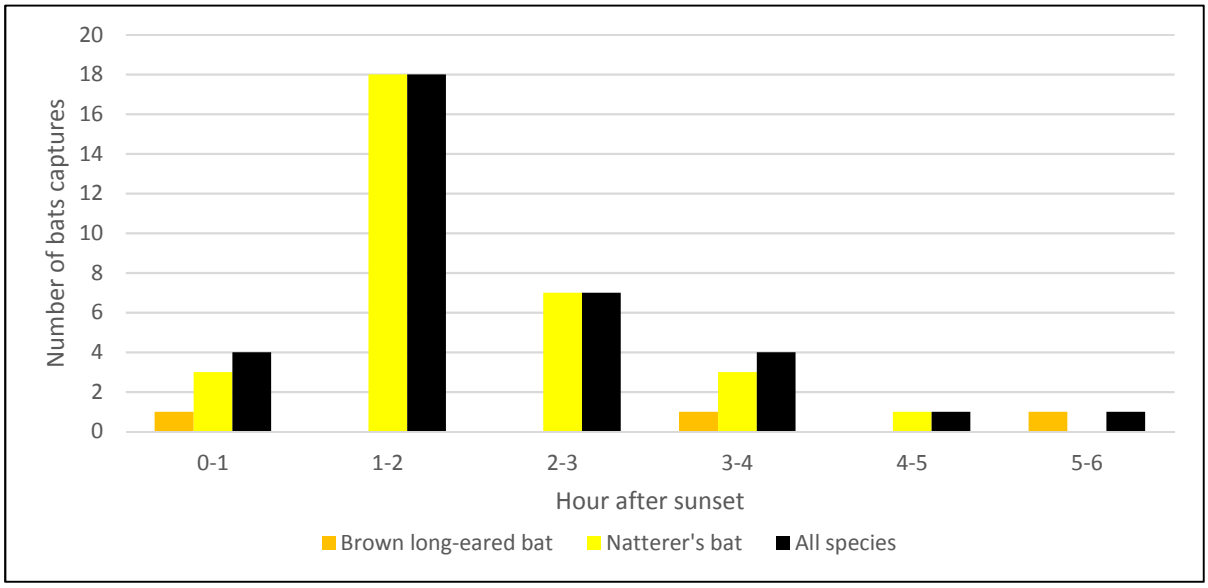

Figure 9: Bat captures by time at Rockley Tramway Tunnel.

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.

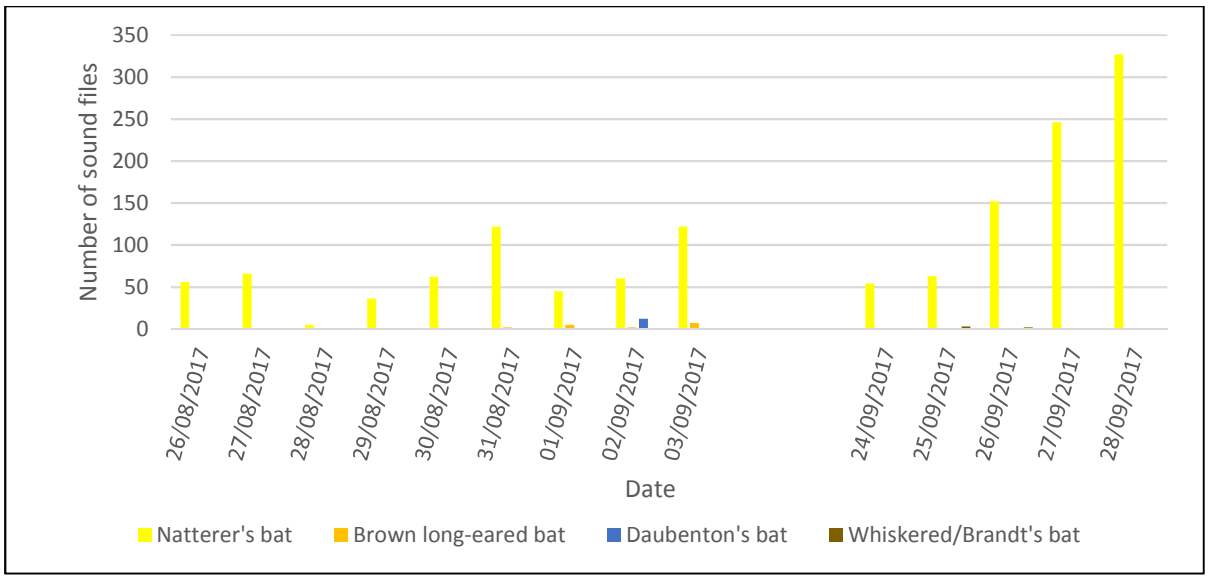

Figure 10: Species composition per night as recorded with a static monitoring device at Rockley Tramway Tunnel.

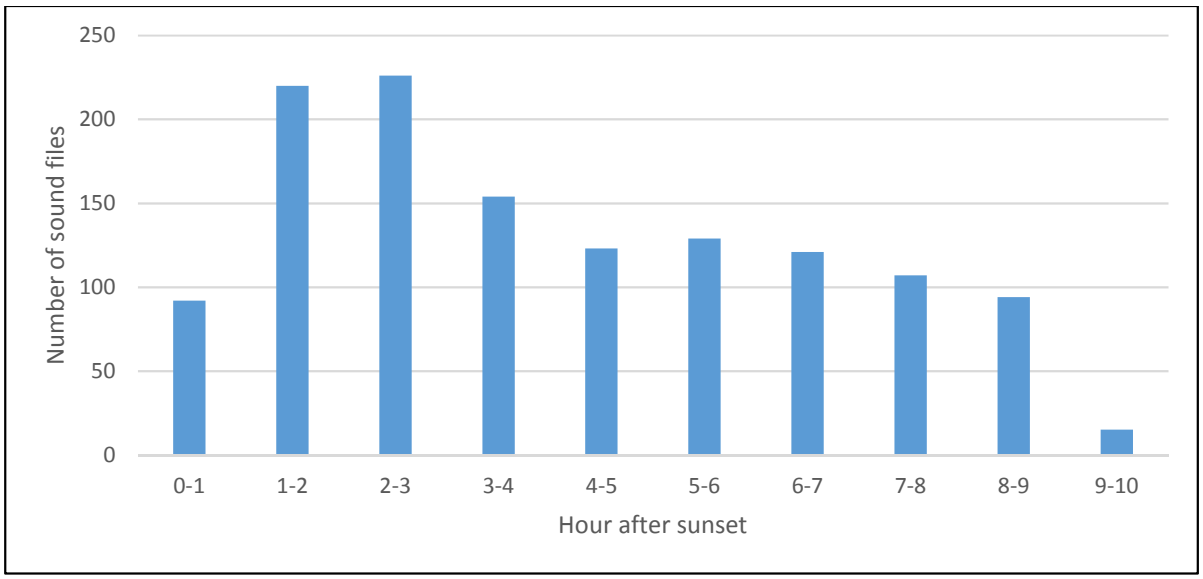

Figure 11: Bat activity distribution through the night recorded from Rockley Tramway Tunnel.

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.

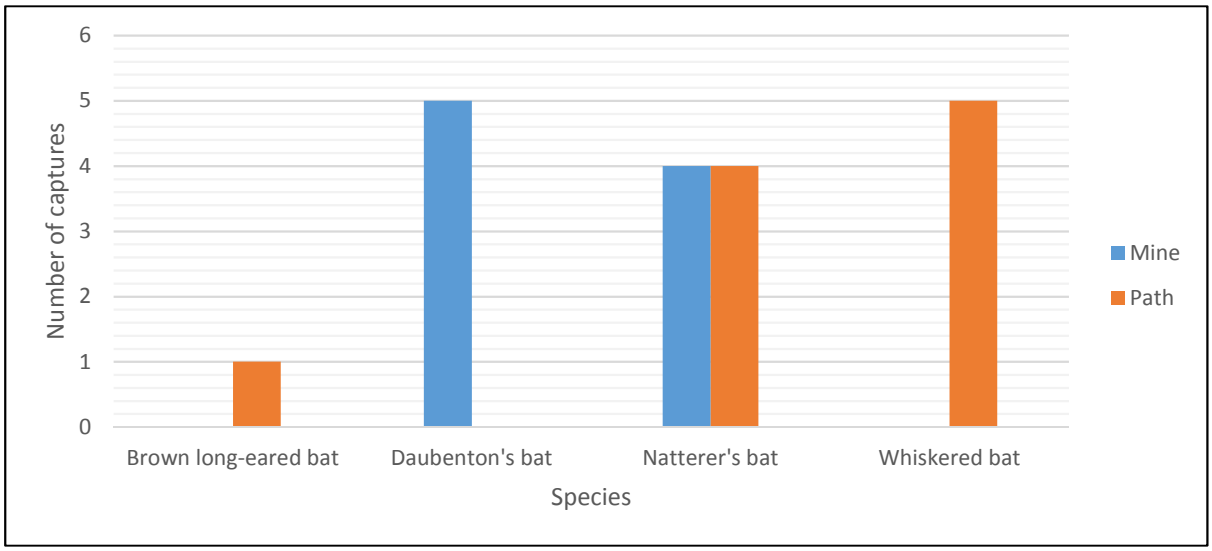

Figure 12: Number of bats caught at each Sheffield Mine trap.

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.

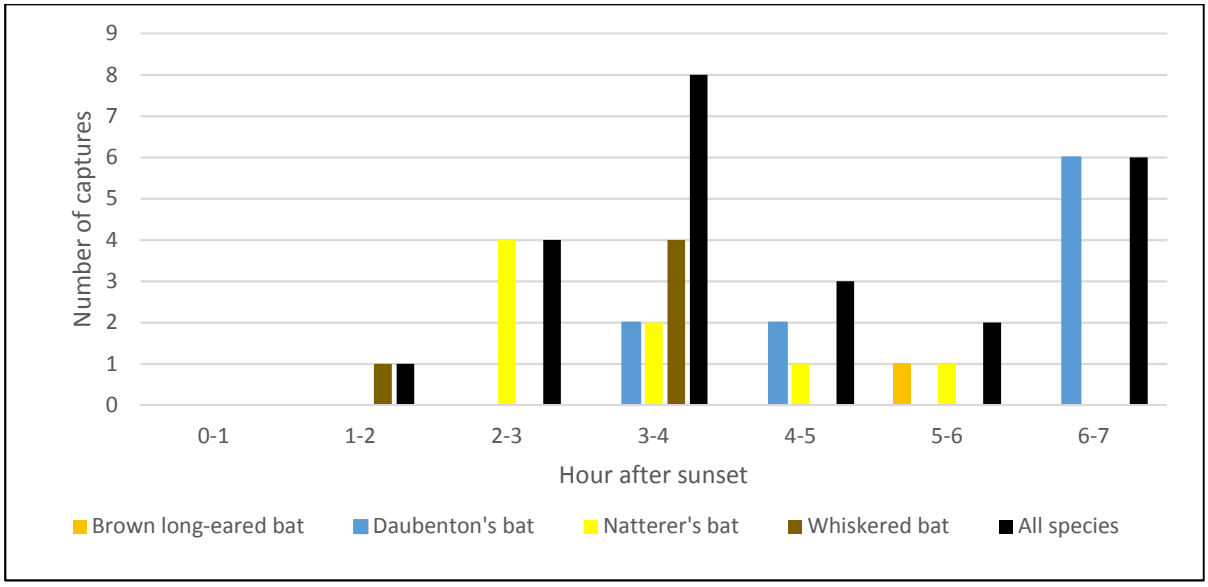

Figure 13: Captures broken down by time after sunset at Sheffield Mine.

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 Neareclif 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.

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Appendix 1. Don Gorge underground sites plan.