South Yorkshire Mine – Hibernation and Swarming Study Findings.

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Background Information

Shortly before the onset of the 2012/2013 winter an abandoned mine, not previously known to be used by bats, was located in the South Yorkshire area. Following discussions with the site owners it was agreed that bat survey work could be undertaken on the understanding that the mine location was not disclosed. This report documents results of 2012/2013 hibernation survey work, a winter 2013/2014 visual inspection/ temperature study and bat swarming survey work carried out in autumn 2015.

Image 1 This image shows main tunnel intersection located approximately 7m in from the mine entrance. An Anabat recording device is shown in the top left of the image. A thermometer was installed on the dry stone support in the top right of the image.

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 comprise 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 approximately 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 the mine's previous extent. An approximate plan of the current accessible mine layout is shown in Image 2. 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.

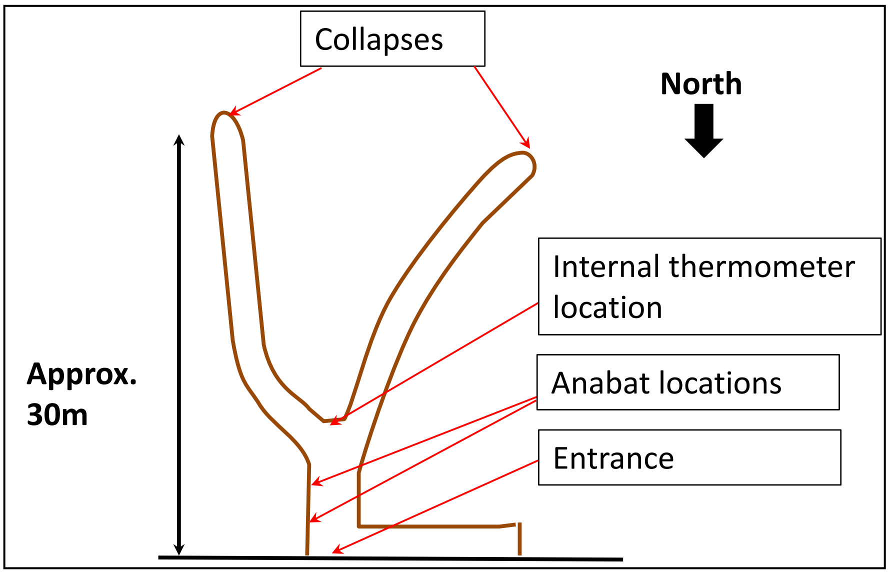


Image 2 Drawing shows an approximate aerial plan of the currently accessible section of the mine. The mine drops in height several meters from the entrance towards the southern end.

During the winter months, bats in northern England engage in hibernation. Hibernation in bats comprises a state of inactivity characterised by lower body temperature, slower breathing, and lower metabolic rates. The ability of bats to hibernate helps to preserve energy reserves at a time of year when weather conditions frequently prevent effective foraging. Different bat species select alternative microclimates for hibernation, with several bat species present in northern England known to make use of both natural (i.e. caves) and human made (i.e. mines and tunnels) underground sites. Underground hibernation roosts are typically characterised by limited airflow which results in low levels of micro-climatic variation (Altringham, 2011).

Autumn bat swarming is characterised by intense bat flight activity in and around the entrances of underground sites, often by multi-species groups of bats. Bats captured at swarming sites often display a strong male bias and autumn swarming has been shown to function as a promiscuous mating behaviour (van Schaik et al., 2015). The species present are usually limited to those that make use of the underground site for hibernation during the winter. Swarming is the major source of gene flow in many bat species (Rivers, Butlin and Altringham, 2005; Furmankiewicz and Atringham, 2007) and is also likely to allow bats the chance to assess hibernation sites ahead of roosting (van Schaik et al., 2015). Autumn swarming is potentially also a means of passing on knowledge of hibernacula locations from adults to young bats (Glover and Altringham, 2008). Internationally autumn swarming has been shown to be most frequently recorded amongst *Myotis* species bats (Parsons et al., 2002), with a range of species shown to display this behaviour in England.

Natterer's bats *Myotis nattereri* have comprised the most frequently recorded species during swarming studies in the Yorkshire Dales (Glover and Altringham, 2008) and North Yorkshire Moors (Rivers, Butlin and Altringham, 2006), whilst a combination of Natterer's bats and Daubenton's bats *M. daubentonii* were most frequently recorded across a number of swarming sites in southern England (Parsons et al., 2003a). The peak period for autumn swarming varies between sites and bat species (Glover and Altringham, 2008; van Schaik et al., 2015; Rivers, Butlin and Altringham, 2006) however this period extends from approximately mid-August to mid-October. Nightly peaks in bat swarming activity have been shown to vary with site and stage of the swarming season, with peak activity most often recorded 4-6 hours after sunset (Parsons, Jones and Greenaway, 2003b; Rivers, Butlin and Altingham, 2006).

Bats have been recorded migrating distances of up to 60km between summer roosts and major swarming sites (Rivers, Butlin and Altringham, 2006). Species composition and abundance during swarming has been shown to correlate with composition and abundance during hibernation at the same site (van Schaik et al., 2015). In addition, remotely logged bat activity has been shown to correlate with bat trapping levels during swarming surveys (Parsons, Jones and Greenaway, 2003b).

Methods

2012/2013 Hibernation/Anabat Survey

A single Anabat static monitoring device was installed within one of the two locations shown on the mine diagram for 115 days between 24/11/2012 and 06/05/2013. Unit sensitivity was set at 6.5 with no timers set. The Anabat batteries were changed when possible and consequently gaps are present between recording periods, particularly earlier in the winter and in the late autumn period, which was largely unrecorded. Recording periods are shown in Table 1.

Recording period	Start date	End date	Recording period	Start date	End date
1	24th November 2012	29th November	10	16th February	23rd February
2	29th November	6th December	11	23rd February	24th February
3	12th December	23rd December	12	4th March	11th March
4	31st December	5th January 2013	13	11th March	18th March
5	8th January	15th January	14	18th March	26th March
6	15th January	22nd January	15	26th March	3rd April
7	22nd January	24th January	16	3rd April	11th April
8	2nd February	6th February	17	11th April	21st April
9	6th February	8th February			

Table 1 Static monitoring periods: winter 2012-2013.

Bat calls recorded were analyed to species level, where possible, using AnalookW with reference to bat call parameters presented in Russ (2012). Mean daily air temperature over the survey period collected from a weather station at Leeds/Bradford Airport was downloaded from the Weather Underground website.

2014 Temperature Study

In order to obtain information on the microclimate in the mine and the level of temperature buffering it displays, a temperature study was undertaken. Two Tinytag thermometers were installed between 05-12/01/2014 with a thermometer inside the mine (see Image 2) and a second located approximately 10m north of the mine entrance. The thermometer installed within the mine also recorded relative humidity. Tinytag Explorer software was used to download themometers and draw the temperature comparison graph.

2015 Swarming Survey

A Pettersson d500x Mark 1 static monitoring device was installed 1m above the mine access for a five night period between 07-12/09/2015. This unit was set to turn on from 30 minutes prior to sunset until 30 minutes after sunrise with an Input Gain of 20 and a Trigger Level of 24. An interval of five seconds was used, resulting in a minimum five second delay between recorded five second long sound files, with this step taken to reduce data volume ensuring the detector remained operational for the full recording period.

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 occurance of 0.8 or greater. Given the similiarity of echolocation calls emiited by Daubenton's bat with those of whiskered bat *M. mystacinus* and Brandt's bat *M. brandtii*, the decision was made to combine these three species within this study. A sample of recorded calls identified from each species were manually anlaysed to confirm species presence at the site.

Weather data during the swarming survey period was taken from recordings made at Leeds/Bradford Airport.

Limitations

During winter 2012/2013 the Anabat battery was changed as regularly as possible however there are significant gaps in coverage, particularly earlier in the winter and in the late Autumn period.

Leeds/Bradford Airport is the closest freely available external temperature data for the mine but is several tens of kilometers distance from the mine and cannot be considered to offer a very accurate refelection of external mine conditions, however this information is included in order to give a general impression of temperatures in northern England at the time.

Anabat or Pettersson sound files are taken as an indication of bat activity abundance, however it should be noted several sound files may be recorded from a single bat, or equally multiple bats may be recorded within a single Anabat sound file. Pettersson settings during the swarming survey ensured a minimum five second delay between sound files. Whilist this will have resulted in some bat activity going unreported it is considered unlikely to significant bias the analysis of sound file spread throughout the recording period.

Findings

2012/2013 Hibernation/Anabat Survey

Over the recording period 61 sound files originating from bats were recorded. Of these files, 59 were considered to have originated from an unidentified *Myotis* species bat, with a single Natterer's bat sound file recorded together with a single sound file originating from an unidentified bat species.

Figure 1 shows the number of sound files recorded by hour. Figure 2 shows the spread of recorded bat soundfiles throughout the recording period against external temperature, with Figure 2a showing temperature throughout the survey period and Figure 2b showing temperature only when the Anabat was operational.

Bat activity was recorded throughout most hours of the day with the low number of recorded sound files unable to provide sufficient resolution to show any clear temporal patterns in activity. Figure 1 does however suggest a slightly higher level of sustained bat activity in the evening, between 18:00 and 23:00 and possibly a spike in activity in the morning around 03:00.

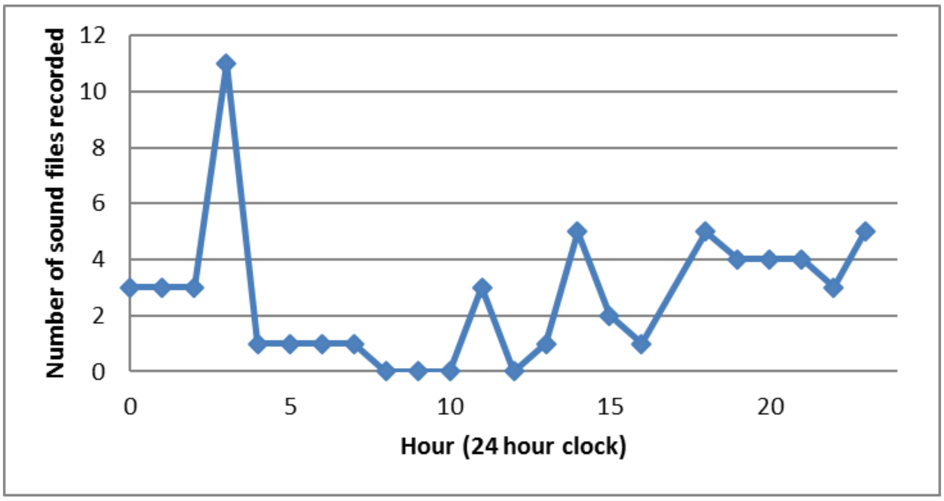
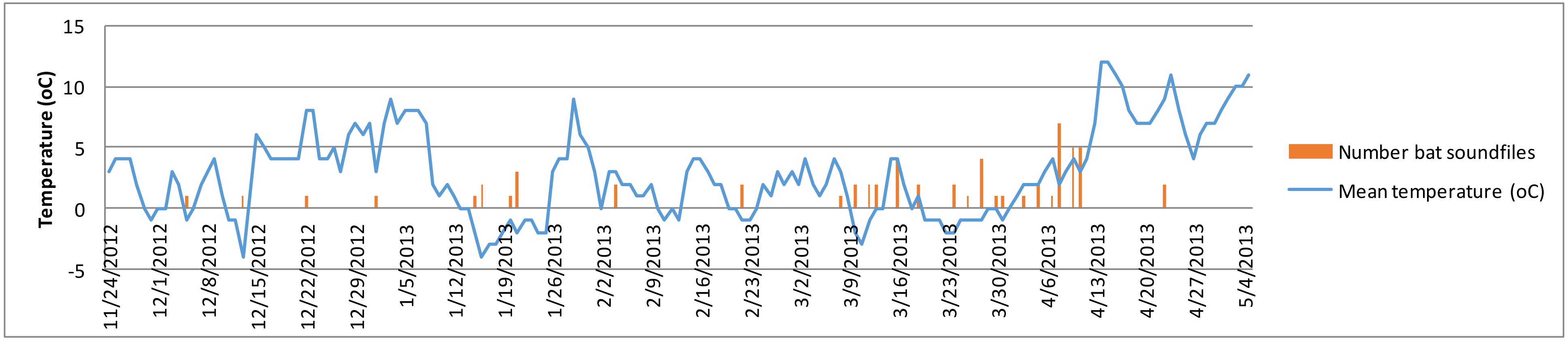


Figure 1 Bat activity against time.

Figure 2 suggests seasonal and weather related patterns in the bat activity. The first and clearest pattern is an increase in bat activity during spring from the beginning of March until mid-April.

The second weaker pattern that can be observed from Figure 2 is a clustering of recorded bat activity during periods of colder weather. An inspection of Figure 2a shows clusters of activity between 12-26/01/2013 and 09-16/03/2013 and occassional additional sound files recorded during periods of cold weather in December 2012 and February 2013. It should however be noted that Figure 2b shows the Anabat detector was frequently out of operation during the earlier part of the year and this appears to have occurred more frequently during periods of milder weather.

a)



b)

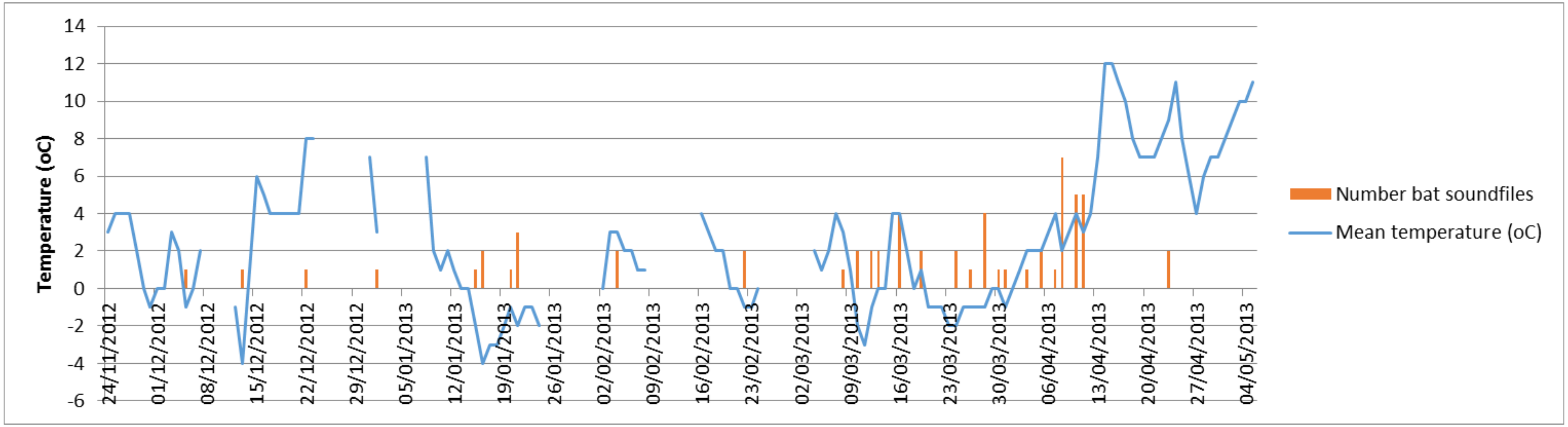


Figure 2 Recorded bat sound files shown against date and mean temperature; a) shows mean temperature throughout the entire survey period, b) shows mean temperature only on the days during which the Anabat recorder was operating.

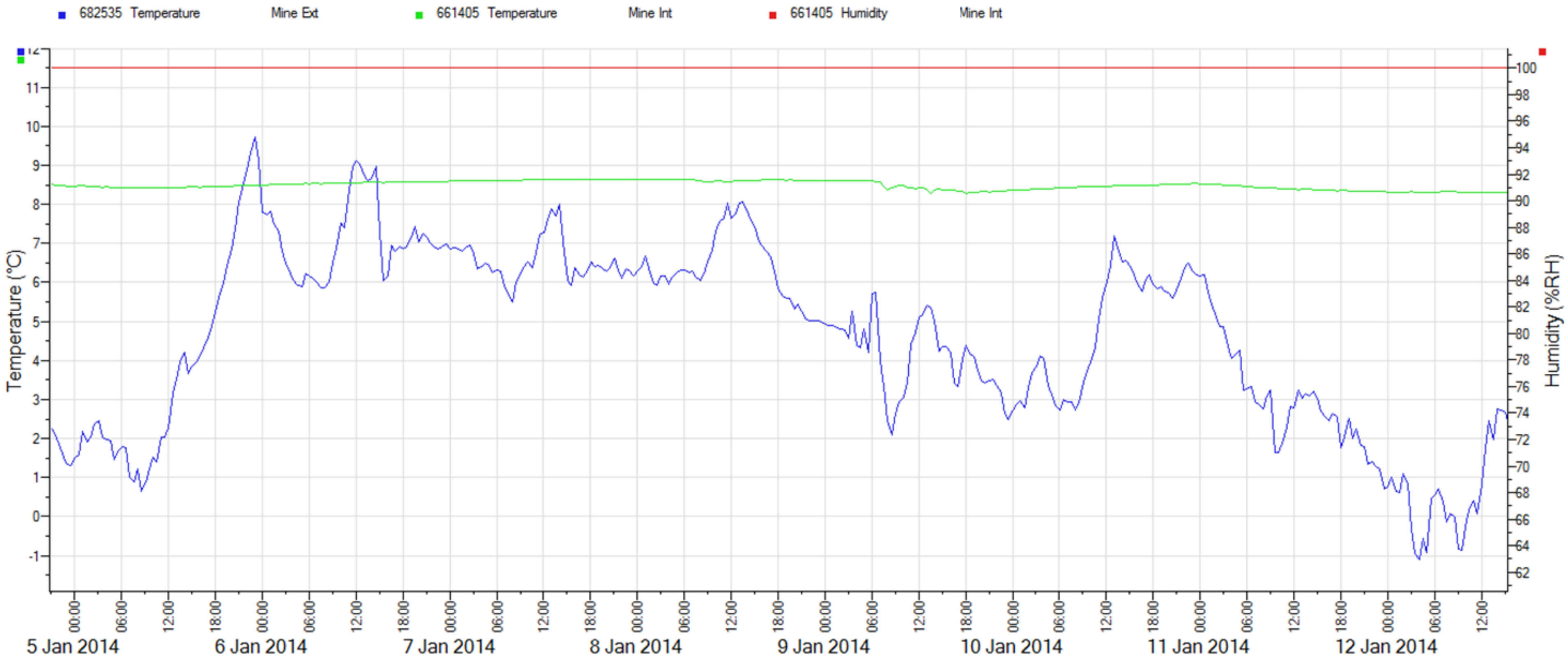


Figure 3 Comparison of temperature inside (green line) and outside the mine (blue line), with relative humidity inside the mine (red line).

2014 Temperature Study

Figure 3 shows that the internal temperature within the mine stays at a very consistent level of approximately 8.5^{o}C even when the external temperature drops below freezing. The level of relative humidity within the mine stayed at 100% throughout the study and this fits with the very humid conditions encountered within the mine during internal inspections.

2015 Swarming Survey

A total of 2942 sound files were recorded during the five night recording period. The spread of recorded sound files between species or species group is provided in Table 2. Table 2 shows that whilst the majority of calls were recorded from common pipistrelle *Pipistrellus pipistrellus*, numerous calls were attributable to either Natterer's bat or the whiskered/Brandt's/Daubenton's bat species group.

Species or species group	Recording night					Total number of sound files
	1	2	3	4	5	
Common pipistrelle	334	201	665	857	462	2519
Daubenton's/whiskered/Brandt's bat	21	10	30	40	114	215
Natterer's bat	57	24	50	26	28	185
Soprano pipistrelle	5	4	2	5	7	23

Table 2 Recorded sound files by species and recording night.

Weather during the survey period was dry and mild (mean temperature = 10-14^{o}C) with low winds; resulting in weather conducive to bat activity. Whilst bat activity levels varied, reasonably high levels of activity were recorded during each of the five nights.

Figure 4 shows the spread of *Myotis* species bat activity with time after sunset, whilst Figure 5 shows the mean and standard deviation of time after sunset recorded from all species or species groups. Common and soprano pipistrelle *Pipistrellus pygmaeus* were not included on Figure 4 given the number of common pipistrelle recorded greatly exceeds those of the *Myotis* species, *Pipistrellus* species are not traditionally associated with autumn swarming and the stone mine displays little potential for *Pipistrellus* species hibernation use.

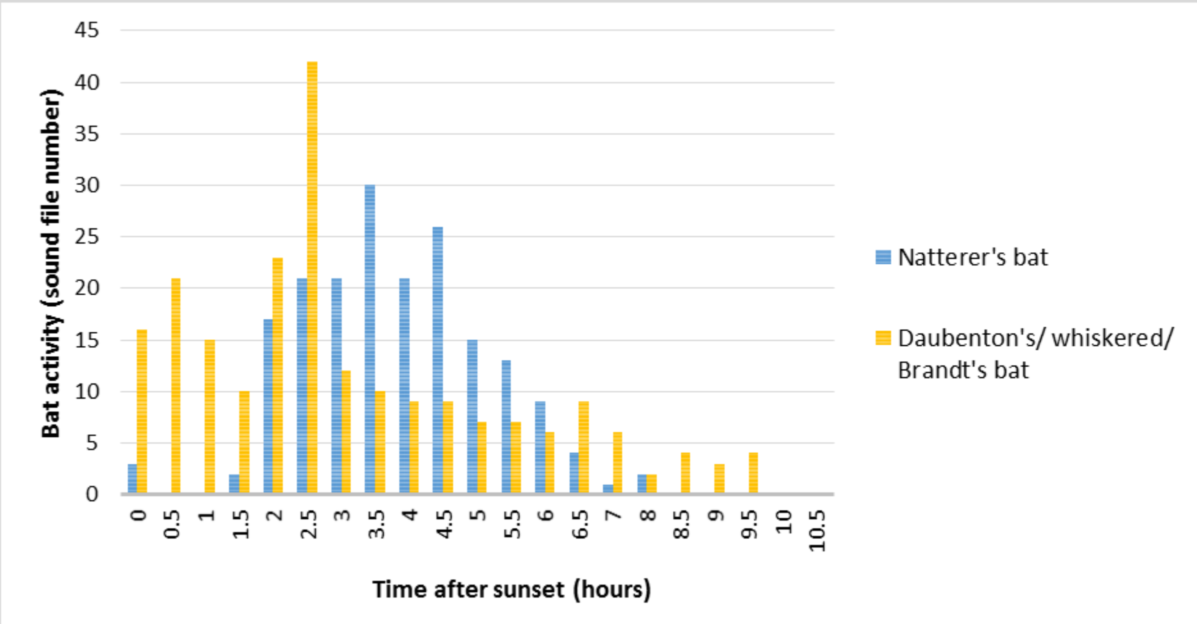


Figure 4 Distribution of *Myotis* species activity with time after sunset.

Natterer's bat activity peaked later in the night than activity by the whiskered/Brandt's/Daubenton's bat species group (see Figure 4), with the mean time of activity also later than recorded for common and soprano pipistrelle (see Figure 5). The spread of Natterer's bat recordings through the night is lower than recorded for other species (see Figure 5).This appears to be due to the lack of any peaks in activity early or late in the night.

It is notable that the Natterer's bat activity peaked 3.5 hours after sunset with the highest levels of recorded activity during each 30 minute period from 2 hours after sunset until 5.5 hours after sunset.

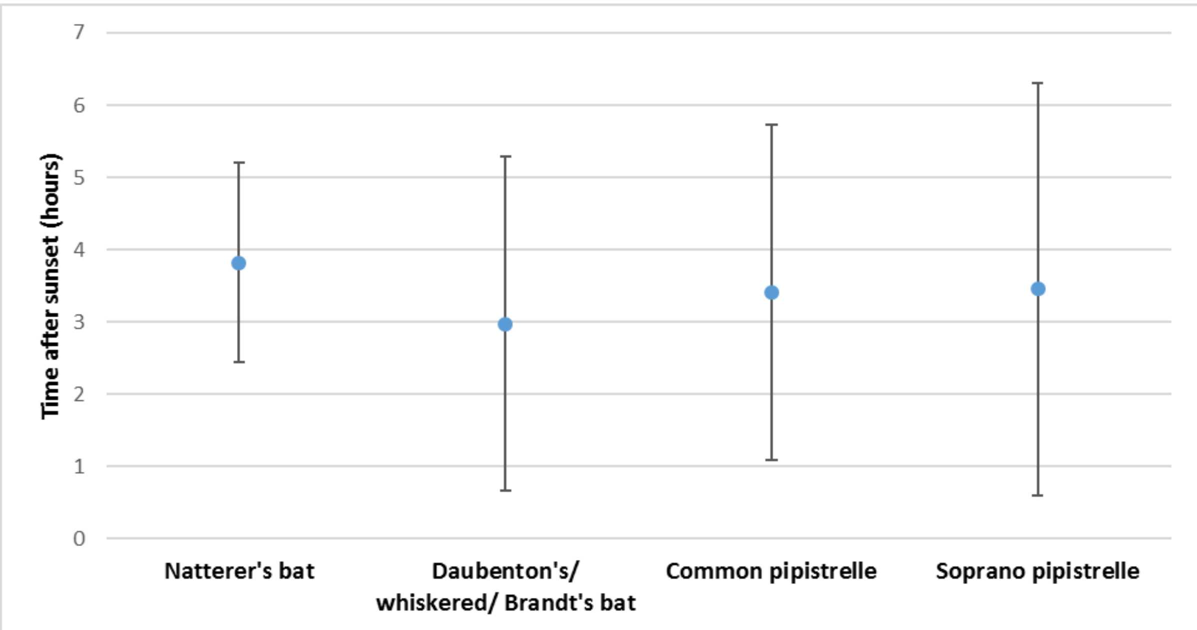
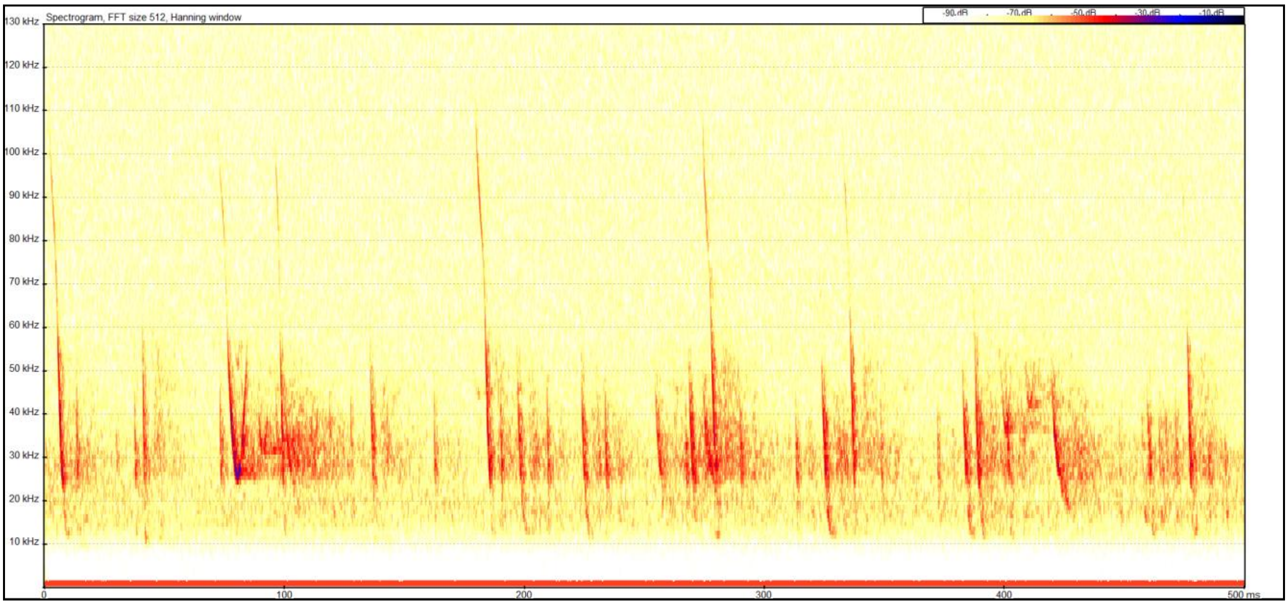


Figure 5 Graph showing the average (mean ±1 standard deviation) time after sunset of recordings by species/species group.

Numerous social calls were recorded during the survey period from species including Daubenton's bat, Natterer's bat and common pipistrelle. Social calls considered likely to have been emitted by Natterer's bat and Daubenton's bat are shown in Images 3a and 3b respectively.

a)



b)

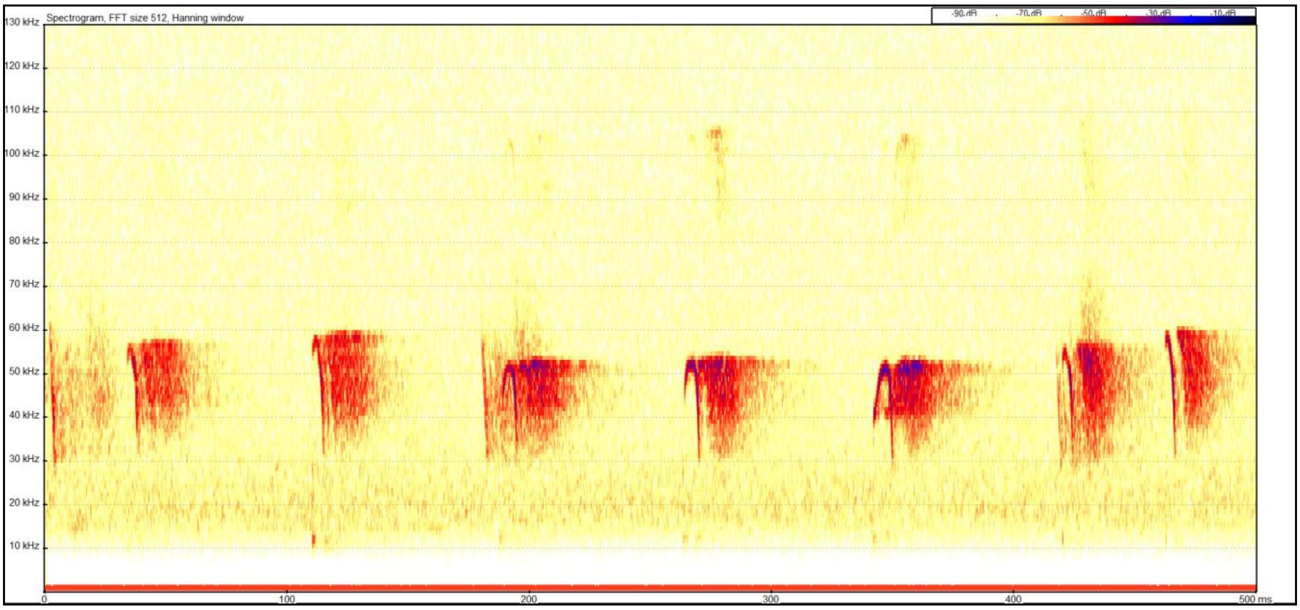


Image 3 Recorded social calls showing Natterer's bat (Image 3a) and Daubenton's bat (Image 3b).

Discussion

The study undertaken is considered to demonstrate usage of the mine as a hibernation roost and a probable autumn swarming site. A number of additional bat activity patterns were also suggested by the data. Although the low number of sound files collected during winter 2012/2013 and the short period of the 2015 swarming survey do not allow a high degree of confidence in survey findings, this study has provided considerable insight into bat usage of the mine.

Hibernation Roost Usage

The present study is taken as evidence that least one *Myotis* species uses the mine as a hibernation roost. Natterer's bat has been confirmed to fly within the mine, and is likely to also roost within it. Whilst survey findings suggest the mine is used by a relatively low number of bats, it is not considered that a study of this type can provide detailed insight into the number of bats using the mine during the hibernation period. Given bats typically rouse once every one to two weeks during hibernation (Altringham, 2011), it is apparent that a moderate to large number of bats would be likely to generate a higher number of sound files than was recorded during this study.

A consistent period of higher bat activity was recorded between early March and mid-April (see Figure 2) suggesting that bat activity within the mine increases in spring. This increase in activity is likely to be the result of bats beginning to emerge from the mine and move to transitional roost sites in other locations. Alternatively, activity at this period of the year may be linked to usage of the mine as a transitional roost. A particular spike in bat activity is evident towards the end of this period, from 06-13/04/2013 (see Figure 2). It should be noted that the air temperature remained cold throughout March 2013 and a late spring was observed, consequently it is likely that the spike in bat activity may have occurred later during winter 2012/2013 than during a typical year.

An additional pattern suggested by the data is that activity increases during periods of cold weather, when the temperature consistently drops below freezing. This suggests that bats most frequently use the mine when other, more marginal, and less insulated hibernation roost sites become too cold. It is possible that the relatively high level of bat activity recorded between early March and mid-April was a result of bats entering the mine due to cold weather at the beginning of this period and then most, if not all, bats exiting the mine at the end of this time.

As shown in Figure 3, the mine displays a remarkably consistent internal temperature of approximately 8.5^{o}C, as recorded only a short distance into the mine (approximately 7m). This temperature is within the range of the mean annual air temperature of the local area (between 8-10^{o}C) and together with the very high relative humidity (100%) indicates that the mine is a non-dynamic system with little airflow (Mitchell-Jones et al., 2010).

Research suggests the mine may actually be too warm to be ideal for hibernation use by locally common *Myotis* and *Plecotus* bat species, which display a preference for mean hibernation roosting temperatures between 4-5.5^{o}C (Nagel and Nagel, 1991). During hibernation, the energy costs of metabolism fall as temperatures approach 1-2^{o}C, although most bats choose to roost in temperatures slightly above this level (Webb et al., 1995). If it is true that the mine's internal temperature makes it sub-optimal for hibernation roosting by the bats that use it, then it would follow that it would be likely to be used mainly during very cold periods when other, more exposed, local roosts are unsuitable.

A comparison of the time of day from which bat activity was recorded highlights only weak patterns. This data would appear to suggest that whilst below ground, bats become active throughout the day, although a slight increase in activity appears to take place during the evening between approximately 18:00 – 23:00. The highest level of hourly activity was recorded at 03:00. This pattern fits with other research undertaken on bats, with studies showing that the circadian clocks within bats become free-running as winter progresses (Altringham, 2011).

Swarming

Myotis bat species recorded during the swarming survey have been classified as either Natterer's bats or bats within the whiskered/Brandt's/Daubenton's bat grouping, with all *Myotis* species present in the England known to exhibit swarming behaviour. The abundance of recordings is similar across both groupings however the mean time Natterer's bats were recorded was later, between 3.5-4 hours after sunset. Natterer's bat recordings also displayed a lower spread in activity times relative to other species, with the highest levels of activity recorded 2-5.5 hours after sunset.

Natterer's bat comprises the bat species most frequently recorded from other documented swarming sites in northern England (Glover and Altringham, 2008; Rivers, Butlin and Altringham, 2006). In addition, Natterer's bat activity recorded during this study peaked at a similar to time to that recorded from other northern England swarming sites (Glover and Altringham, 2008). Taking these considerations into account, it is considered that Natterer's bats are highly likely to engage in autumn swarming behaviour at the mine.

Whilst bats of the whiskered/Brandt's/Daubenton's bat grouping may also swarm at the mine, the evidence demonstrating this use is less compelling than for Natterer's bat. This species group recorded an earlier peak activity time, which fell close to that recorded from common and soprano pipistrelle at the same site. The wider spread of activity through the night, including early evening activity, suggests that whiskered/Brandt's/Daubenton's bats also forage on site. It is considered probable that the activity recorded from this species group was a combination of commuting, foraging and some swarming activity.

The presence of Daubenton's bat at the mine has been shown with a high degree of confidence through the recording of a diagnostic social call during the swarming survey. The area surrounding the mine entrance is dry with the closest water feature, a minor brook, located approximately 400m from the site. Such habitat would not comprise typical Daubenton's bat foraging habitat and consequently the presence of a social calling Daubenton's bat in this situation supports the assertion that bats of this species engage in some level of autumn swarming at mine.

Further Survey

Whilst the mine is unlikely to be used by large numbers of bats for swarming or hibernation it presents a site that is easily accessed for further study. Static monitoring devices and other equipment is safe from theft given the secluded nature of the site. It would be appealing to repeat the hibernation study using a bat detector recording continuously over the whole hibernation period season. This bat detector would be coupled with two temperature loggers, one inside the mine and the other outside the main entrance. Such a study would help confirm the findings of the 2012/2013 survey, whilst also being enabling a more robust consideration of bat activity against temperature.

Further investigation of swarming could comprise static monitoring survey undertaken for one or more weeks per month during the swarming period. Static monitoring survey could be coupled with the use of a night video camera system to observe the mine entrance during peak swarming times, in order to record bats entering or leaving the mine. Direct evidence of stone mine entry/exit by bats would demonstrate that bats recorded during this period were engaged in autumn swarming, as oppose to other activities such as foraging. Consideration could also be given to harp trapping at the site, with bat capture enabling more definite species identification and potentially providing a gauge to bat numbers using the site.

Further Considerations

Local geology has not resulted in the production of natural caves and consequently the mine is likely to comprise one of the few subterranean bat hibernation sites available in the surrounding area. It is clear that this mine is suffering from collapses, reducing its extent and possibly resulting in changes to air movement inside. There is considered to be a relatively high risk that this mine may be lost completely to bats in the medium term due to a future collapse close to the mine entrance. It is not clear that any safe management action could be taken to secure this structure and recommendations of this kind are outside the scope of this report.

References

Altringham, J. (2011) Bats: from evolution to conservation, 2nd Edition. Oxford University Press, Oxford.

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

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

Mitchell-Jones, T., Bihari, Z., Masing, M., Rodrigues, L. (2010) Eurobats: protecting and managing underground sites, 3rd Edition. UNEP/Eurobats.

Nagel, A., Nagel, R. (1991) How do bats choose optimal temperatures for hibernation. Comparative Biochemistry and Physiology. 99. Issue 3: 323-326.

Parsons, K.N., Jones, G., Davidson-Watts, I., Greenaway, F. (2003a) Swarming of bats at underground sites in Britain – implications for conservation. Biological Conservation 111, 63-70.

Parsons, K.N., Jones, G., Greenaway, F. (2003b) 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. (2005) Genetic population structure of Natterer's bats explained by mating at swarming sites and philopatry. Molecular Ecology 14, 4299–4312.

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.

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

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.

Webb, P., Speakman, J., Racey, P. (1995) How hot is a hibernaculum? A review of the temperatures at which bats hibernate. Canadian Journal of Zoology. 74: 761-765.