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British Islands Bats



**Volume Four
2023**



Welcome to the fourth volume of British Islands Bats.

Thank you to all of our contributors and readers for your patience this year. It has been a very busy 15 months since the last volume was published, for all bat workers, which can be seen in the number of articles in this volume. As editors, we always find it incredibly inspiring to read about the activities of bat folks across the British Islands (England, Scotland, Wales, Northern Ireland, Isle of Man and the Channel Islands) and the continuing enthusiasm people have to study and conserve these incredible animals.

One of the people who inspired us personally was the late Tony Hutson. He passed away back in February and is greatly missed. You can find a fitting obituary to Tony on the Sussex Bat Group website (with a recording of the celebration of his life that took place in March) <https://www.sussexbatgroup.org.uk/>.

You may have spotted the addition of the International Standard Serial Number (ISSN) on the top right of the cover page of this volume. We have added the number to all of the previous volumes online as well. Thank you to those of you who suggested having an ISSN to facilitate sharing and referencing of British Islands Bats.

For Volume Three we have also added a note to the article '*π•pipistrelle: an ultra-inexpensive, handheld device for citizen bat science*' on page 121 explaining that the model of commercial detector mentioned was based on the author's experience from an early 2019 model, which has been further developed since. As with all of the papers submitted to British Islands Bats, the views expressed are those of the authors. If you wish to follow-up on anything in an article please do contact the corresponding author directly (a contact email address is provided for every paper we publish).

Publication of this journal is a collaborative enterprise and we are grateful to everyone who has supplied content for Volume Four. Thanks also to the Bat Conservation Trust (BCT) for continuing to host British Island Bats online, but please note we are an independent publication. Please do get in touch if you would like to make a submission to Volume Five.

Best regards,



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Cover image: Noctule *Nyctalus noctula* in flight taken in late summer at a Cornish Wildlife Trust reserve in East Cornwall. Adults and volant young of the year were emerging from a free hanging oblong box with foam board partitions (see British Islands Bats Volume One page 149, Figure 5). © John Kaczanow.

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Multi-Point Activity Surveys: A novel technique for the analysis of the movements of Daubenton's bat *Myotis daubentonii* (Kuhl, 1817) on Waterways

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Background

Landscape-scale data on bat movements are often gained through radio tagging and telemetry, which can provide information on roost locations, nightly movements and commuting routes (Collins, 2016). Whilst effective and accurate, these methods have several disadvantages. The cost of equipment for radio telemetry may be prohibitively expensive; the availability of skilled and appropriately licensed surveyors may be limited (Hughes *et al.*, 2021); and access to private land to track bat movements may be difficult to obtain (Hourigan *et al.*, 2008). Additionally (and partially as a result of resource limitations), the number of individual bats from which meaningful data can be gained in a single study is often low. We sought to develop a robust, repeatable and cost-effective method for monitoring the movements of multiple bats at a landscape scale. To that end, we have developed the Multi-Point Activity Survey (MultiPAS) technique, which requires minimal field training and equipment, is focused on publicly accessible land, and can be undertaken under a Class 1 bat licence. The technique focuses on waterways which, in the case of our pilot study, was a network of urban canals north of Birmingham.

Daubenton's bat *Myotis daubentonii* has a documented affinity for water (Altringham, 2003), with their roosts generally being found within 200m of lentic and riparian habitats (Ngamprasertwong *et al.*, 2014). Though they are known to be encountered readily in woodlands, they utilise linear features (Dietz and Kiefer, 2014) such as waterways to commute nightly from their roosts, emerging and flying directly to their preferred feeding areas, with each bat showing high fidelity to one or two foraging sites (Altringham, 2003; Rainho and Palmeirim, 2011) which are usually within 3km of the roost (Altringham, 2003). The MultiPAS method combines acoustic monitoring with visual observations of bat passes along waterways, and is based upon the fact that Daubenton's bat is known to commute almost exclusively within 1m above water's surface (Altringham, 2003) with an average of 15.8cm above the surface (Kalko and Schnitzler, 1989). This predictability affords surveyors the opportunity to use torches to aid in visual observations of individual bats as they undertake their commuting flight.

We have developed and field tested the MultiPAS method and used it effectively to gather data on multiple individual bats (in our case, up to 80 individuals per survey) to determine main commuting routes, key hop-on and hop-off points and important crossing points (authors' own unpublished data). The applications for the data are diverse, and include population monitoring, assessing potential impacts for developments along waterways, establishing mitigation effectiveness where watercourses are changed, identifying bat commuting routes and suggesting candidate sites for the establishment of dark corridors.

The MultiPAS method can be used as an alternative to invasive and prohibitively expensive methods of radio tagging and tracking and can provide large datasets of robust, quantitative data on a landscape scale in a repeatable manner, on multiple bats in a single survey. It can be carried out with minimal field training using readily available materials. Further applications have also been demonstrated to be effective for roost counts at tunnels, and activity surveys at barriers, aqueducts and bridges. Here, we present two main models for MultiPAS and several supplementary applications.

Survey Design

General methods

The fundamental survey design for the study is that of teams (usually four) of surveyors being positioned at set intervals **Error! Reference source not found.** along sections of a waterway (Figure 1). Utilising a combination of acoustic monitoring and visual observations, the movements of individual Daubenton's bats are tracked as they commute from their day roosts to their foraging areas. Equipment comprising bat detectors and red LED torches is positioned facing the opposite bank. Upon observing each bat passing a survey point, the survey team at that position use two-way radios to give verbal cues to alert adjacent teams to anticipate the ingress/pass of a bat.

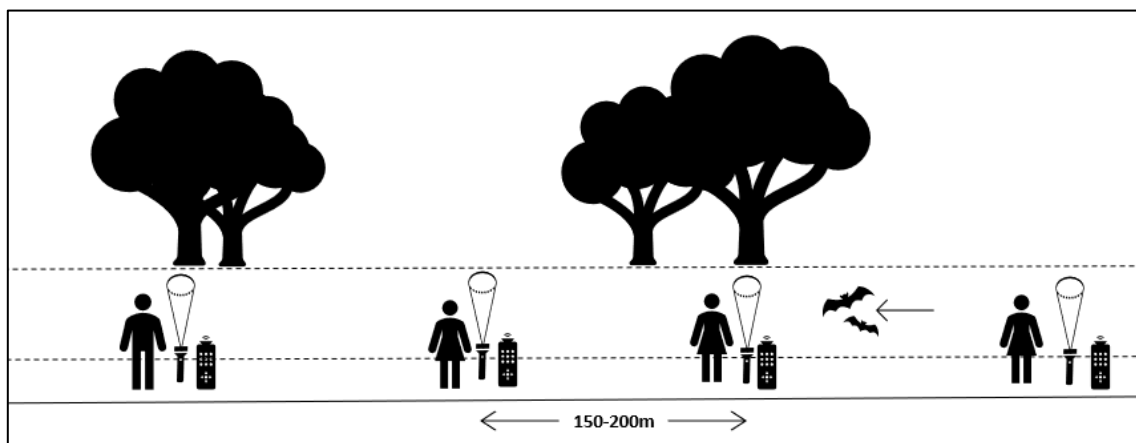


Figure 1: Indicative positioning and spacing of survey teams and equipment for MultiPAS. Icons used with permission from Microsoft Office 365.

Timings

The MultiPAS method was developed with the aim of observing, recording and analysing the movements of Daubenton's bat with a focus on commuting movements at emergence only. To that end, the survey timings were designed accordingly. Daubenton's bat is reported to have mean emergence times ranging (in minutes after sunset) from 28 ± 12 minutes to 105 ± 15 minutes (Swift and Racey, 1983; Jones and Rydell, 1994; Warren *et al.*, 2000; Altringham, 2003; Lucan, 2009). The species has also been documented to have mean emergence times on average of 14 minutes earlier during the post-parturition period (Lucan, 2009), an observation borne out in the recent work by Annette Faulkner (2022) who recorded emergence at sunset ± 40 minutes in June, but sunset +20 post-parturition. The species-specific protocols developed for monitoring Daubenton's bat of the National Bat Monitoring Programme's Waterways Survey (Bat Conservation Trust, 2020) comprise a start time of sunset +40 mins after sunset and a duration of 60 minutes. For MultiPAS surveys, this timing was altered to accommodate the anticipated earlier emergence of the post-

parturition period, with **surveys commencing at sunset +30 minutes and lasting for 60 minutes**. We would recommend adopting standard activity survey effort with regard to number of visits per season/month as per the Surveys for Professional Ecologists: Good Practice Guidelines (Collins, 2016).

Equipment

Key pieces of field equipment to undertake MultiPAS surveys are as follows: each team should have a bat detector – heterodyne is adequate, however we recommend a live-view, full spectrum unit such as the Wildlife Acoustics EchoMeter Touch 2 Pro (with auto-ID turned off so that popups do not obscure the display). Each team also requires a red LED torch¹ and a two-way radio with which to communicate with other teams.

Field Identification

For our pilot studies, auto-identification on the EchoMeter Touch 2 Pro detectors (Wildlife Acoustics Inc., 2018) was disabled due to the display being obscured during notifications. As the most commonly encountered species (Daubenton's bat, noctule *Nyctalus noctula*, common pipistrelle *Pipistrellus pipistrellus*, and soprano pipistrelle *P. pygmaeus*) are all readily identifiable by their distinct sonograms (Hughes *et al.*, 2020) with moderate field training, surveyors were able to accurately separate these species from other bats. The calls of Daubenton's bat comprise a largely frequency modulated structure, giving a 'dry' call which is in contrast to those of other common species (e.g. *Pipistrellus* and *Nyctalus*). Calls sweep from a mean of 81.1kHz to a mean of 29.4kHz, with a peak frequency of 41.8 – 56.5kHz (mean 47.0kHz). The calls also exhibit a qCF component mid-call (Russ, 2013), lending the pulses a sigmoidal profile (Newson and Berthinussen, 2019). In addition, the habit of this species of flying immediately above water creates distinctive missing frequencies (Russ, 2013), often called 'comb filtering'. This, coupled with visual observations of medium-sized bats flying low over the water affords surveyors confidence in field identifications with only a moderate amount of field training.

Survey Models

Prior to survey work, daytime reconnaissance surveys and aerial mapping should be used to plan survey locations for both models presented below. This should include safety considerations such as access, walking routes and parking.

Model 1: Linear Model

The aims of the Linear Survey Model were to identify 'hop on' and 'hop off' points used by bats along the waterways, inferring commuting routes to foraging grounds. In our study we used 16 locations approximately 200m apart² (named Alpha to Papa) covering a 3km section

¹ In our initial field testing, we recorded multiple incidences of light aversion when using white torches for the survey method, with some individual bats turning back along their route. We have not made any observations of avoidance behaviour when using red LED torches, and so for welfare (as well as survey efficacy) reasons, would not recommend using white lights for the MultiPAS method.

² The number of survey locations in the study area should be divisible by the approximate number of teams available. At our spacing and in a relatively flat landscape, four teams at 200m intervals can all hear each other on two-way radios, but greater spacing and a greater number of survey teams may alter radio efficacy.

of canal (Figure 2). Each survey covered four survey points with subsequent visits ‘moving up’ the line of the points and overlapping the previous survey’s end point (e.g. survey 1 – Alpha to Delta; survey 2 – Delta to Golf, etc.), covering the whole survey area in five survey visits and providing survey coverage with no gaps between survey points.



Figure 2: Linear survey model Pilot Study survey points, spacing at approximately 200m.

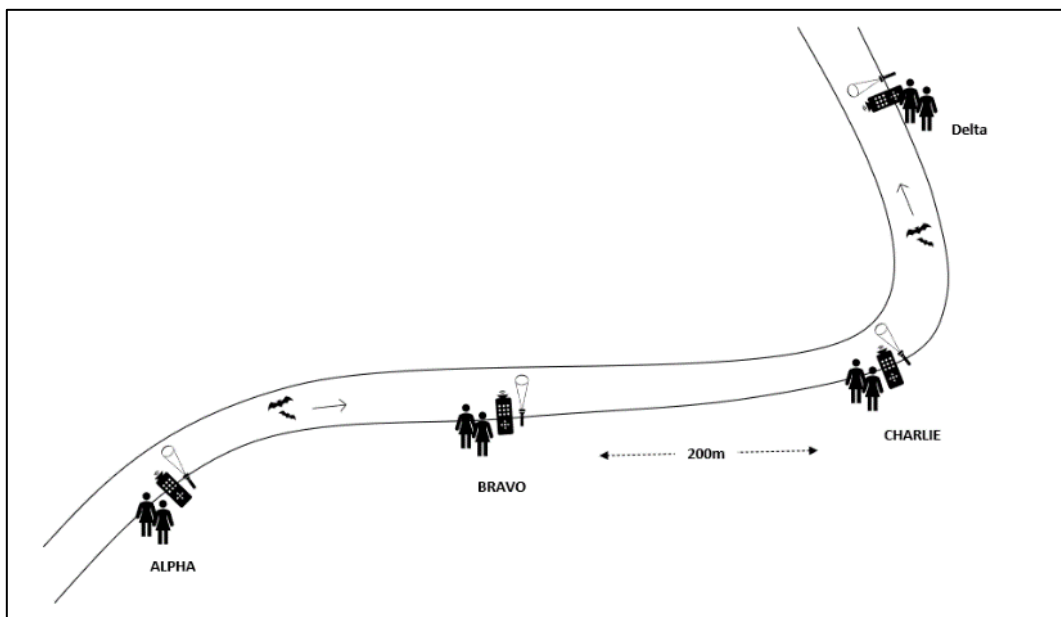


Figure 3: Indicative positioning of surveyors and equipment for MultiPAS Linear survey model. Icons used with permission from Microsoft Office 365.

At each survey point, equipment was deployed with LED torch positioned with the beam illuminating the opposite bank and bat detectors also facing the opposite bank (Figure 3). Teams watched the beam for passing bats and upon each bat pass, used their two-way radio to alert the other teams of the bat’s position and direction of travel (e.g. ‘Alpha, bat north’). This alerted the adjacent team in the direction of travel to anticipate a bat pass in a set

amount of time³ based on the distance between survey points. For each bat pass data recording comprised time, first and last contact points, and direction of travel.

Model 2: Junctions Model

The aims of the Junctions Survey Model were to identify commuting routes at canal junctions. The surveys comprised three teams (Alpha, Bravo and Charlie) positioned 125m from the canal junction with the fourth team (Zulu) from the centre of the junction to provide information on movements from that vantage point (Figure 4). Observation and recording method is the same as for the Linear Survey Model, with the exception that direction of travel is recorded as 'in' or 'out' (of the junction). We also placed additional torches across each arm of the junction at Zulu survey point to assist in visual observations.

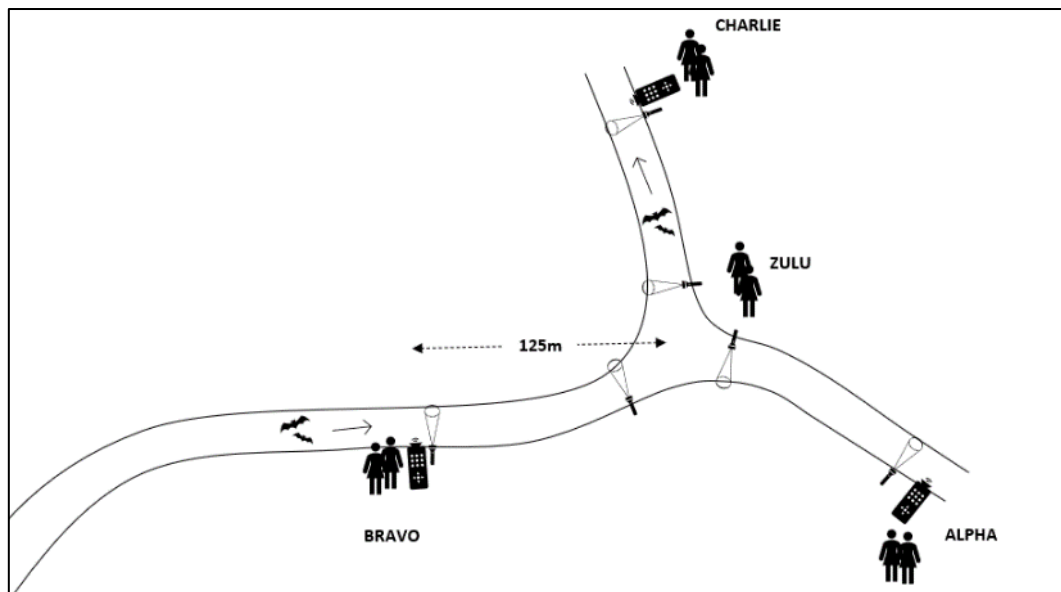


Figure 4: Indicative positioning of surveyors and equipment for MultiPAS Junctions survey model. Icons used with permission from Microsoft Office 365.

Data Interpretation

Interpretation of MultiPAS results is essentially based on 'gaps' in data. For example, multiple bat passes from Alpha to Bravo, but not reaching Charlie, would indicate a 'hop off' point between Bravo and Charlie; similarly a lack of passes at Alpha, but starting at Bravo and going through to Delta indicate a 'hop on' point between Alpha and Bravo. Identified (or likely) routes can then be inferred using aerial imagery to look at likely foraging grounds. An example of this from our pilot study is shown in Figure 5. This can then be substantiated by further crossing point-style, ideally with Night Vision Aids to confirm bat flight routes. Data (flight routes) can also be mapped over open source light pollution data (e.g. NASA, 2021) to provide contextual environmental information.

³ We undertook surveys timing bats along several waterways (straight and curved) in order to estimate transit time between survey points. Speeds ranged from 3.2 mps to 8.3 mps with a median of 5.9mps and a mean of 6.1mps (Figure 6.21) which gives an anticipated 200m transit time of ± 32 seconds. This is in line with RHIDDs results which ranged from 2.8mps to 8.3mps with an average speed of 5.3mps (Middleton, 2006).

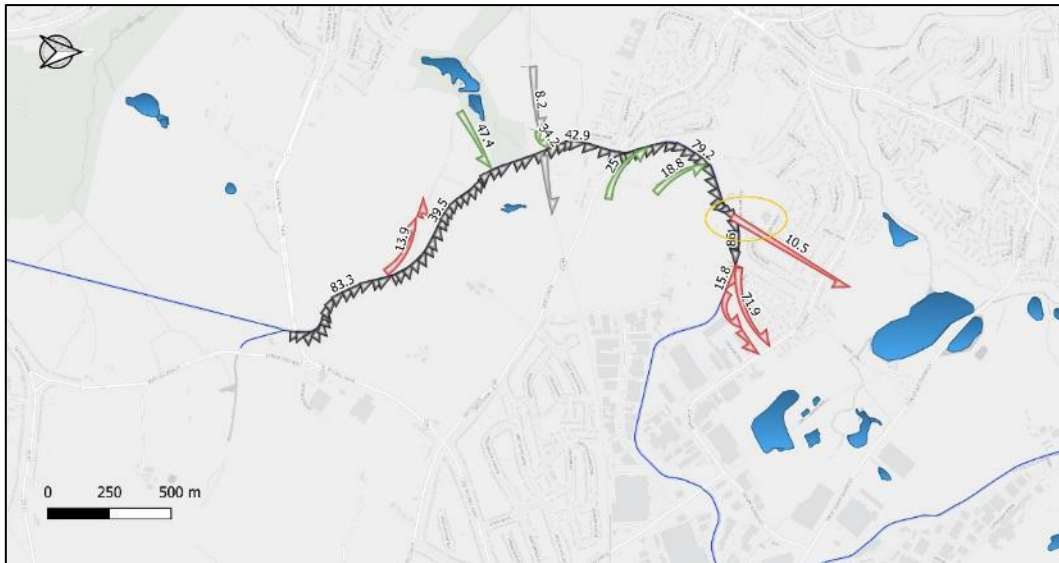


Figure 5: Routes taken by bats at pilot study site, with green arrows showing identified ‘hop-on’ points and red arrows showing ‘hop-off’ points and egress routes. Numbers denote mean percentage of bats using each route section during section surveys.

Further Applications

The MultiPAS method principles (i.e. a combined utilisation of visual and acoustic observations aided by bat detectors and red LED torches based on multiple simultaneous survey points) were used to undertake further investigations of the behaviour of commuting bats in the urban landscape, comprising:

Assessment of behaviour at barriers

We used the MultiPAS method to record the behaviour of Daubenton’s bat at structures which were deemed to have the potential to represent a barrier to commuting bats (e.g. motorways or major roads) where they were crossed by canals (e.g. via underpasses and aqueducts). Bats were recorded passing through or over structures (Figure 6) and any deviation from routes were recorded. Each bat’s transit was recorded as either ‘through’ (passing through the structure entirely), ‘over’ (continuing along canal but crossing over the road/barrier) or ‘turn’ (turning upon approaching the barrier; not crossing or passing through).

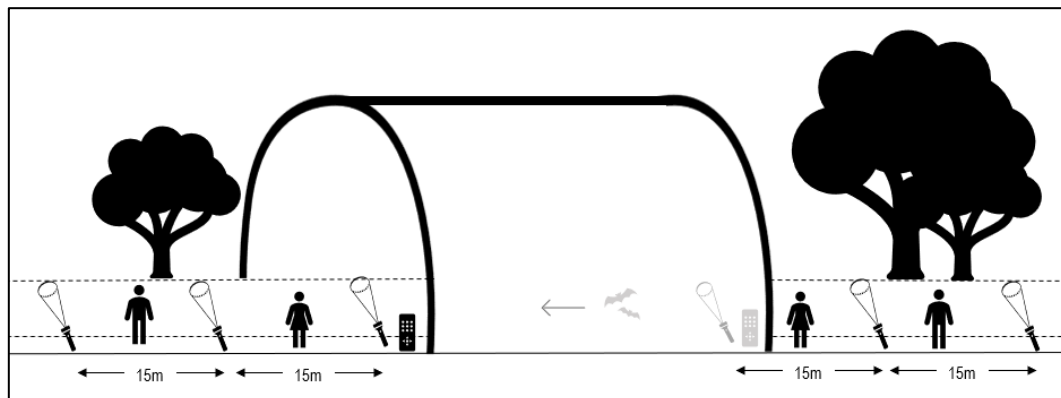


Figure 6: Diagram of surveyor positioning for road barriers survey method. Icons used with permission from Microsoft Office 365.

Assessment of behaviour at tunnels

The method for surveying canal tunnels uses the general principles of MultiPAS (torch, observation and anticipated timings). Both sides of a tunnel were surveyed simultaneously (Figure 7). Data allowed surveyors to infer commuting numbers in each direction, as well as the number of tenant (roosting) bats within each structure (total number of bats exiting the tunnel before any entered, plus (after first ingress) total bats minus total bats in).

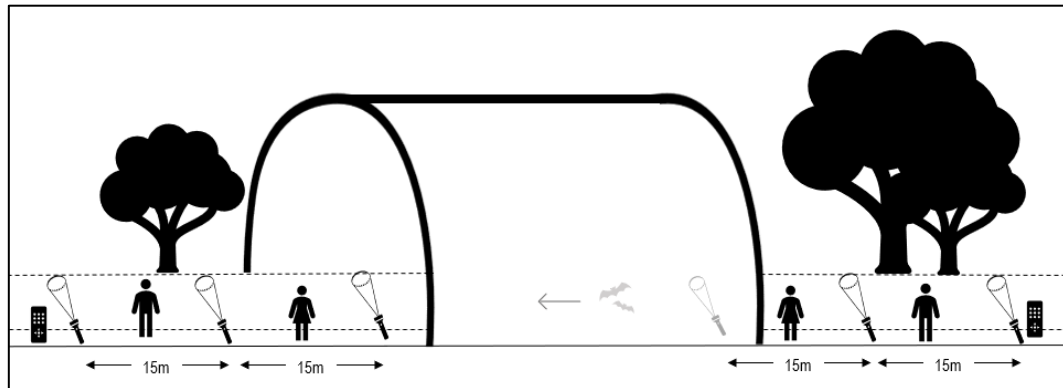


Figure 7: Diagram of surveyor positioning for tunnels survey method. Icons used with permission from Microsoft Office 365.

Constraints and Considerations

Behaviour at locks

We undertook surveys at canal locks in order to assess the suitability of MultiPAS surveys in the vicinity of locks. Specifically, the aim was to assess how far away from a lock survey teams need to be positioned in order to have confidence in bats flying through the surface-level (defined as the area up to 75cm above the water's surface) torch beams, making the MultiPAS method viable. We determined that the distance from the bottom lock at which bats returned to 'cruising altitude' (i.e., were visible in torches) ranged from 20m to 100m, with a mean of 35.69m and a median of 25m. The point at which 95% of bat passes were captured by the MultiPAS technique was 70m from the lock.

Floating plants

We made a number of ad-hoc observations that surveys where there was an abundance of floating vegetation (particularly floating water fern *Azolla filiculoides*) in the centre of the channel, Daubenton's bats abandoned their normal flight routes and instead flew along the adjacent hedgerows, adding a constraint to survey efficacy.

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Acknowledgments

The authors would like to thank Wildlife Acoustics for their support in the project by providing EMT2 Pro bat detectors as part of their Scientific Product Grant scheme. We would also like to thank the volunteers from the Birmingham and Black Country Bat Group's research group: the Urban Bat Project.

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The use of photography to count and identify bats

Mandy Tomas

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Members of the Reiver's Bat Research Group have developed the following technique to count and identify which species of bats are present at an English Heritage property, with as little disturbance to the resident bats as possible.

We have been fortunate to count the obvious bats at the property throughout the year, both in the Priory and adjacent Manor House. The Priory is a known maternity roost for Daubenton's bats *Myotis daubentonii*, soprano pipistrelle *Pipistrellus pygmaeus* and common pipistrelle *P. pipistrellus* bats. The Manor House is a probable maternity roost for Brandt's bats *Myotis brandti* as a juvenile has been found in the building, with the identification confirmed by DNA analysis. Whiskered bat *M. mystacinus* have also been recorded in the building. Both buildings are hibernacula, used by at least six species of bat between them, the additional species being Natterer's bat *M. nattereri* and brown long-eared bat *Plecotus auritus*.

The bats are counted once each month so that a record can be made of how the bats make use of the building. The bats use a high number of different locations, with 49 different roosts identified to date across the two buildings. Within the Priory, bats are found all year in the vertical crevices between the wooden timbers of the tower floor and the stone walls, approximately 17m high. Bats also roost in the narrow gaps where decorative stone pillars meet squared stone work, at a height of c.12m. There is no easy way to count these bats (Figure 1).



Figure 1: A typical view of a bat roosting by a stone pillar, c.12m up. © Neil Tomas.

Previously counts were conducted with binoculars and high-powered torches as the ambient light is not strong enough to identify potential bats; with the same area counted by two or three people. Sometimes dark patches that one surveyor is certain is a bat causes 'discussions' with another surveyor who is equally convinced it is a piece of wood or droppings. The method used to resolve this was to make a note of the location of the suspected bat or dark area and to see if it moved between months or was present over several surveys, if the former it was recorded as a bat.

We decided that a more accurate method was required for the counts.

Using a Canon 5D camera body with a 100-400mm lens (set at 400mm) and a Canon flashgun on a tripod, photographs are taken of all areas where one surveyor has quickly looked for and found potential bats (Figure 2).



Figure 2: Photographing bats around the tower without a tripod (left) and more stable images with use of a tripod (right).

As the area where a bat might be roosting is greater than the distance of the roof timbers to the floor, as the bat is in the gap to the side of the timber, the distance must be estimated either by photographing another part of the tower where no bats can be seen or by using an area where there are droppings. The aperture must be set as small as possible, although f8 has been found to be the best setting to give the depth of field at this site and is adjusted as required with the strength of the flash. No more than two photographs are taken of each bat/group of bats to reduce potential disturbance - however usually only one photo is taken. This method has much less impact on bats than shining torch light on them for prolonged periods. A laser pointer is used to locate the area to be photographed (Figure 3). The photographs are taken under licence.



Figure 3: Using a laser pointer to ensure the correct area is photographed, again reducing the number of images required. Three bats can be seen in this image, from 17m below only a dark area was visible. © Neil Tomas.

Taking images of dark areas has greatly increased our accuracy at counting bats (Figure 4) and ensured that bats are not counted in error (Figure 5).



Figure 4: Two *Pipistrellus* bats can be seen in the corner, with a third further along; 17m up. There is also a dark mark to the left, which is not a bat. © Neil Tomas.



Figure 5: This dark mark, again 17m up, is not a bat. © Neil Tomas.

This method has usually doubled or even quadrupled the number of bats found roosting (Figures 6 and 7).



Figure 6: Five bats tucked behind a stone pillar, 12m up. © Neil Tomas.



Figure 7: Two *Pipistrellus* bats, close together looking down, 17m up. © Neil Tomas.

This technique has also thrown up some interesting anomalies. We had thought that the Daubenton's bats and soprano pipistrelles roosted separately and this is the case for the majority of year, however they were found to be roosting together in August 2022 (Figure 8).



Figure 8: Daubenton's bats and soprano pipistrelles roosting together around the tower. © Neil Tomas.

Indeed, on our most recent survey a photograph taken of a bat, assumed to be *Pipistrellus*, turned out to show a *Myotis*, potentially a Natterer's bat, with two (previously unseen) *Pipistrellus* in the same shot (Figure 9).



Figure 9: A *Myotis* bat, potentially Natterer's bat, and two unseen *Pipistrellus* bats, roosting 17m up. © Neil Tomas.

These photographs are record shots, they are not intended to be exhibition quality, they are a quick way to count bats with minimum disturbance, we can now 'discuss' the number of bats present and any potential identification later via email! It is true to say the certain 'non bats' are now well-known having been repeatedly photographed!

A great advantage of this technique is that when the buildings are open to the public, we can show them where the bats are; we show them the images and we can usually tell them the species and about the importance of bats to the ecosystem and these buildings as bat roosts. The bats in these buildings are used to the public wandering around far below them and in fact during the late summer juveniles (we presume) will do fly pasts even when a wedding is going on!

If anyone is using a similar technique, or has any suggestions to improve ours, please do get in touch.

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***Pipistrellus* species hibernacula in Northumberland.**

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In 2014 a data search for Northumberland returned only six known bat hibernation sites, of which three were used by *Pipistrellus* species, and as everyone needs a hobby, this was the beginning of a project to find more hibernacula within the county. If we don't know where the bats are hibernating, we are not able to protect or even monitor these sites.

As a result of surveys undertaken as part of this study between 2015 and 2023, there are now 39 known hibernacula within Northumberland, with the sites used by *Myotis*, *Pipistrellus* and *Plecotus* species. *Pipistrellus* species have been found in 23 different sites, with 13 of those being used exclusively by *Pipistrellus*, nine sites have included one or two brown long-eared bats *Plecotus auritus* and *Myotis* species were found in two sites. Most of these sites are used by small numbers of *Pipistrellus*, typically one to six bats, but intriguingly, more than 40 *Pipistrellus* have been found in four hibernacula.

***Pipistrellus* hibernacula**

Pipistrellus hibernation sites are generally in buildings and above ground, not like typical hibernation sites in caves, tunnels and cellars. Churches account for a third of the *Pipistrellus* sites we have found since 2015. Unlike *Myotis* and *Plecotus* hibernacula these sites do not have an obviously high humidity; none include standing or running water and none of the *Pipistrellus* found in this study have been below ground level.

Most of the hibernation sites are within stone buildings, churches, halls, castles and even a lime kiln, although two sites are within rock features and two are wooden sheds. Internally, these buildings are generally exposed stone with bats choosing crevices between stone and wooden rafters, roof timbers or panelling (Figure 1), alternatively if wood is not present, *Pipistrellus* will hibernate in crevices between stones (Figure 2).



Figure 1: Examples of *Pipistrellus* hibernation roosts between stone and wood.

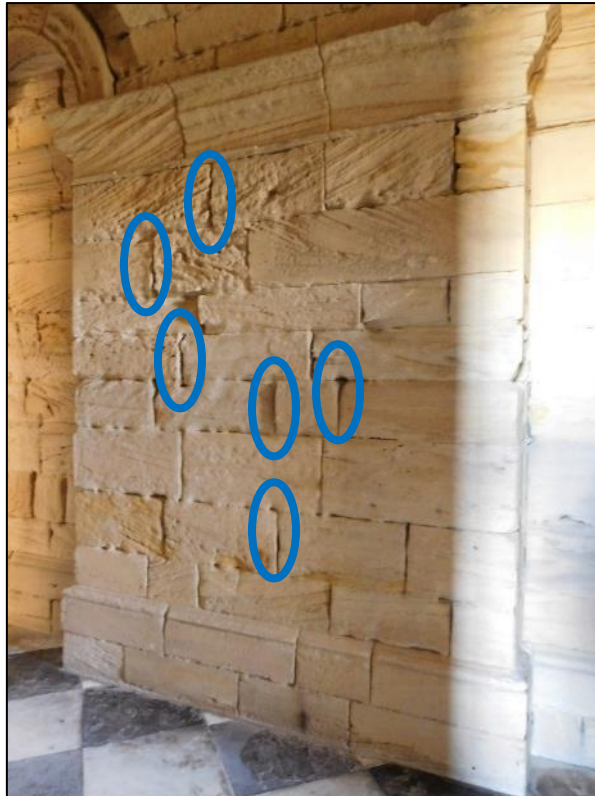


Figure 2: Examples of *Pipistrellus* hibernation roosts in stone crevices.

The nature of the buildings makes finding bats challenging, some sites no longer have internal floors and some sites, for examples churches, have high roof lines making survey difficult. The survey techniques have evolved from just using a torch, to include torch and binoculars (Battersby, 2010) and then to photographing ‘suspected’ bats for later identification to lessen disturbance caused by light. *Pipistrellus* have been recorded hibernating singly, in small groups and in one site 40+ individuals hibernate in a narrow gap along a rafter. Individuals can be tucked deep into the crevices at all heights within the building; in one site the main roost area is 17m up and in another, bats are roosting as low as 500mm from the floor. Final counts are always a minimum, it is not always possible to know if there is one bat in a crevice or many more tucked behind out of sight; and realistically we are not finding all the bats present.

In each building the exact roost location was recorded, with height and distance to a feature noted and a photograph taken for future reference (Figure 3). These ‘photo guides’ provide a full picture of the bat use of the building, invaluable in case of future repairs. During each survey it was noted which crevices bats are in, allowing that crevice to be checked subsequently for hibernating bats and a record of bat movement was made during each winter.

Visual hibernation count surveys were undertaken once a month between November and March and the number of *Pipistrellus* found was recorded. Of the four sites with high numbers of *Pipistrellus*, the church has been monitored since 2014, the castle and hall since 2018 but the bastle site was only discovered in February 2022.

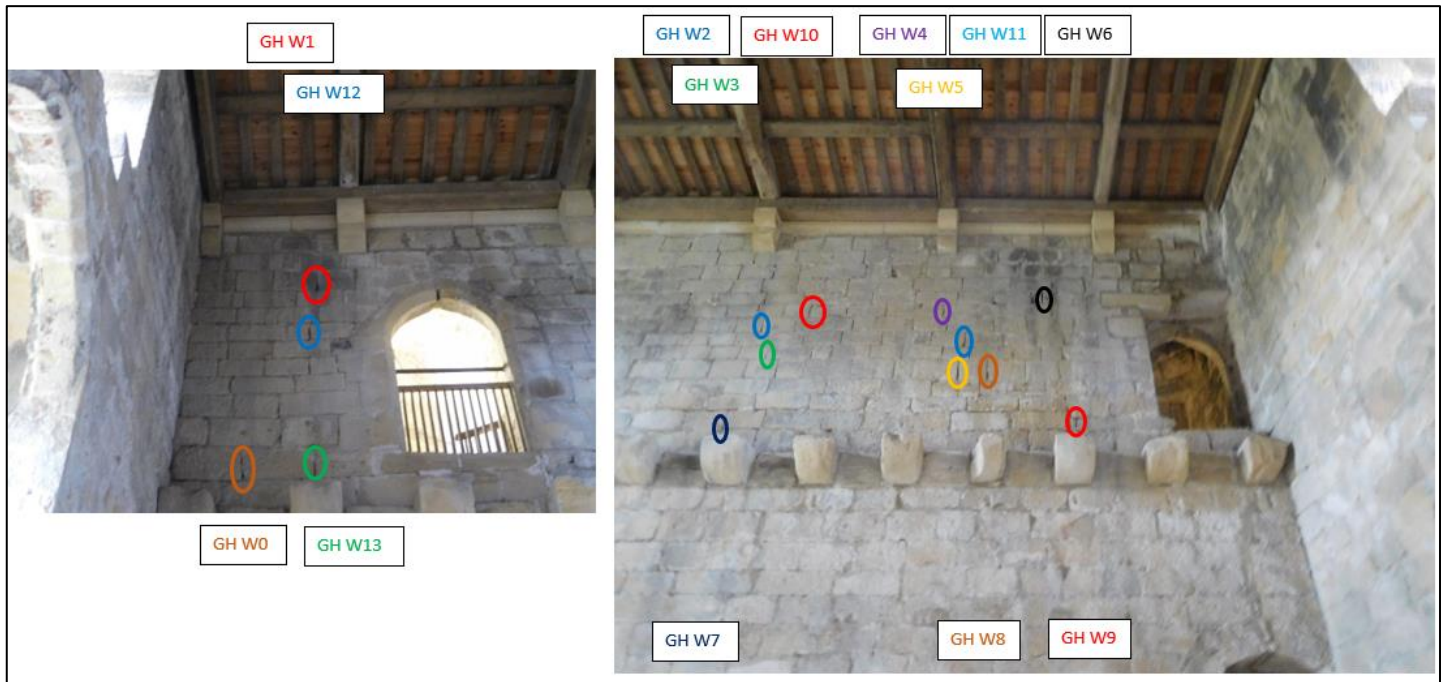


Figure 3: Individual hibernation roost locations.

The number of bats found per month in the four mass hibernacula show a normal distribution which peaks in January (Figure 4), echoing data from previous hibernation studies. Bats are known to move into hibernacula from the end of October, with numbers peaking in January and moving away by the end of February (Sandel *et al.*, 2001); similarly, Neubaum *et al.* (2006) recorded bats moving between autumnal roost sites, hibernacula and vernal roosts.

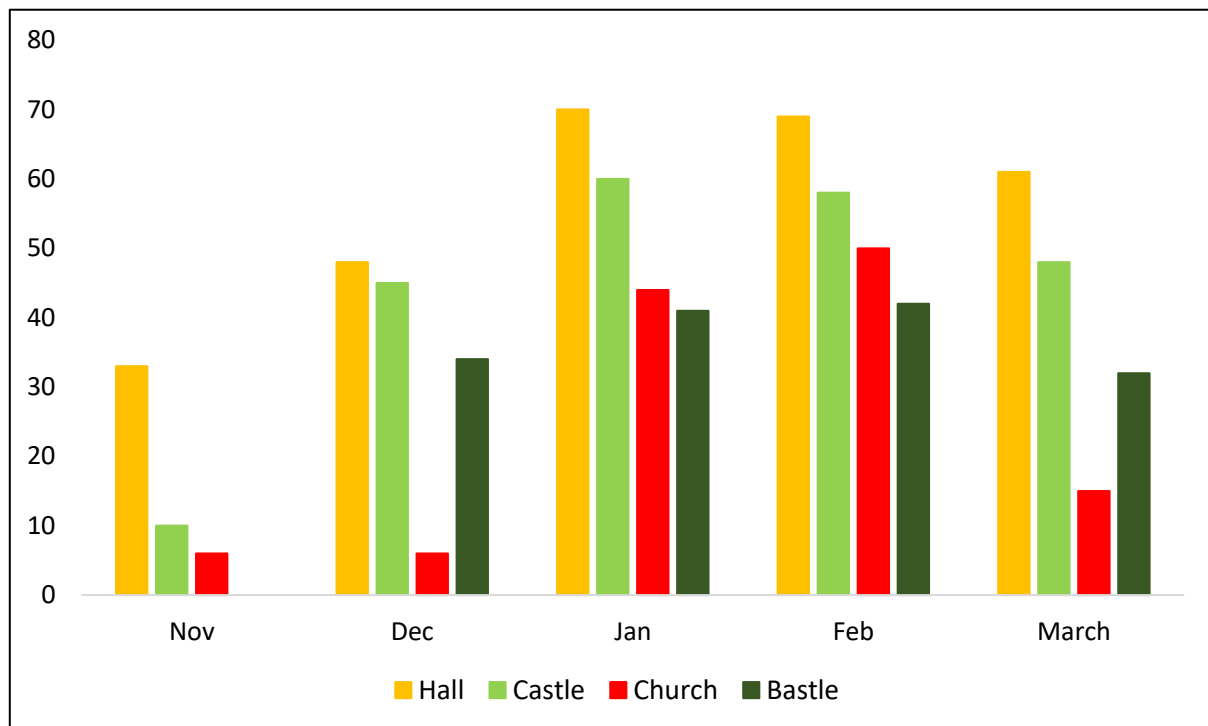


Figure 4: Maximum count per month for each mass *Pipistrellus* hibernacula.

In Europe Korsten *et al.* (2016) have shown that *Pipistrellus* undertake frost swarming outside of hibernation sites in early winter, with bats seen flying around buildings, landing on and even entering the building. This behavior takes place when there is a strong temperature drop to below 0°C, with bat flight activity beginning an hour after sunset for around 60-120 minutes (Jansen *et al.*, 2022). Frost swarming has not yet been recorded in the UK.

In winter 2022-23 five sites were selected to investigate if frost swarming does occur in Northumberland. Three of the sites, a castle, a church and a hall, have all been used by a minimum of 50 *Pipistrellus* for hibernation, while the other two sites, a manor house and a priory, are known hibernacula with maximum counts of 11 and 17 *Pipistrellus* respectively (author's own unpublished data).

Visual counts were undertaken each month from November to March to understand how the bat numbers fluctuated across the winter (Figure 5). The counts followed a normal distribution; however fewer bats were present in the church than expected.

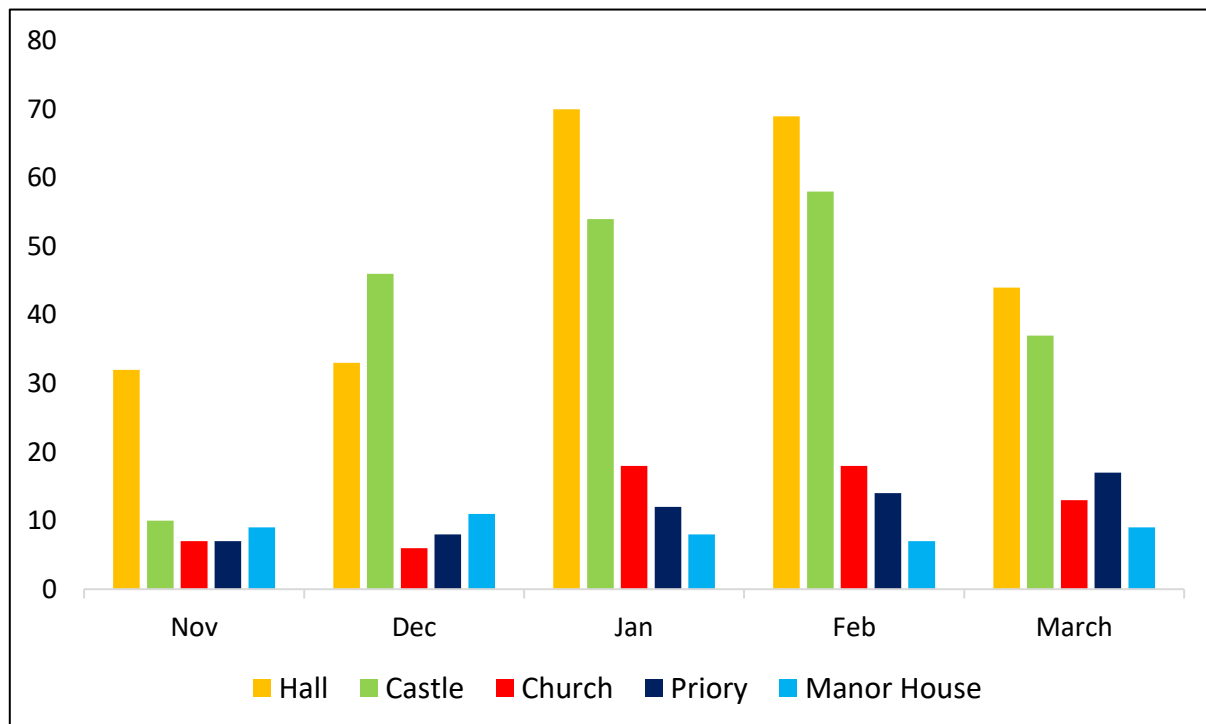


Figure 5: Maximum *Pipistrellus* count per month, November 2022 to March 2023.

These five sites differ from the sites studied by Korsten *et al.* (2016) and Jansen *et al.* (2022) in that access was possible into the buildings. This allowed for constant acoustic monitoring to take place rather than relying on surveyor availability on the nights when the temperature dropped to check for frost swarming behaviour. AudioMoth full-spectrum acoustic loggers were used to record bat activity and ibuttons were used to record the external temperature. The AudioMoths were configured to record at 192kHz with medium gain, recording continuously into eight-second sound files (Somerset Bat Group, 2020). The AudioMoths were set to record continuously for 120 minutes during the second and third hour after sunset (Jansen *et al.*, 2022) every night from 25th of November 2022 to 17th of March 2023, a total of 113 nights.

Acoustic data was collected from all sites on every night during the survey period. SonoBat 30.0 was used to analyse the bat echolocation calls, noise files were removed and sound files with bat tonal features were analysed automatically using SonoBatch Classifier, UK Middle. A total of 460,870 eight-second audio files were collected of which 116,391 files were flagged to include bat tonal features in SonoBat. Once manually verified in SonoVet, 10,182 files were found to contain bat passes. In this study a bat pass is defined as one or more echolocation pulses of the same species recorded within one sound file (Roche *et al.*, 2011). It is important to note that bat passes are an index of bat activity rather than a measure of numbers of individual bats (Collins, 2016).

Pipistrellus were not routinely recorded to species level during the hibernation surveys as many bats were deep within crevices, however certain individuals could be identified based on morphology. Common pipistrelle *P. pipistrellus* and soprano pipistrelle *P. pygmaeus* were present within all five hibernacula, with both species occasionally roosting in the same crevice. SonoBat was used to classify *Pipistrellus* calls to species level and confirmed the presence of soprano pipistrelle in all five sites. Common pipistrelle was the most abundant species, with 75.86% of the bat passes recorded attributed to this species, while soprano pipistrelle calls accounted for 24.12%.

The number of bat passes peaked on similar nights across all five sites (Figure 6). When the data was split by species, the same trends were apparent (Figures 7 and 8).

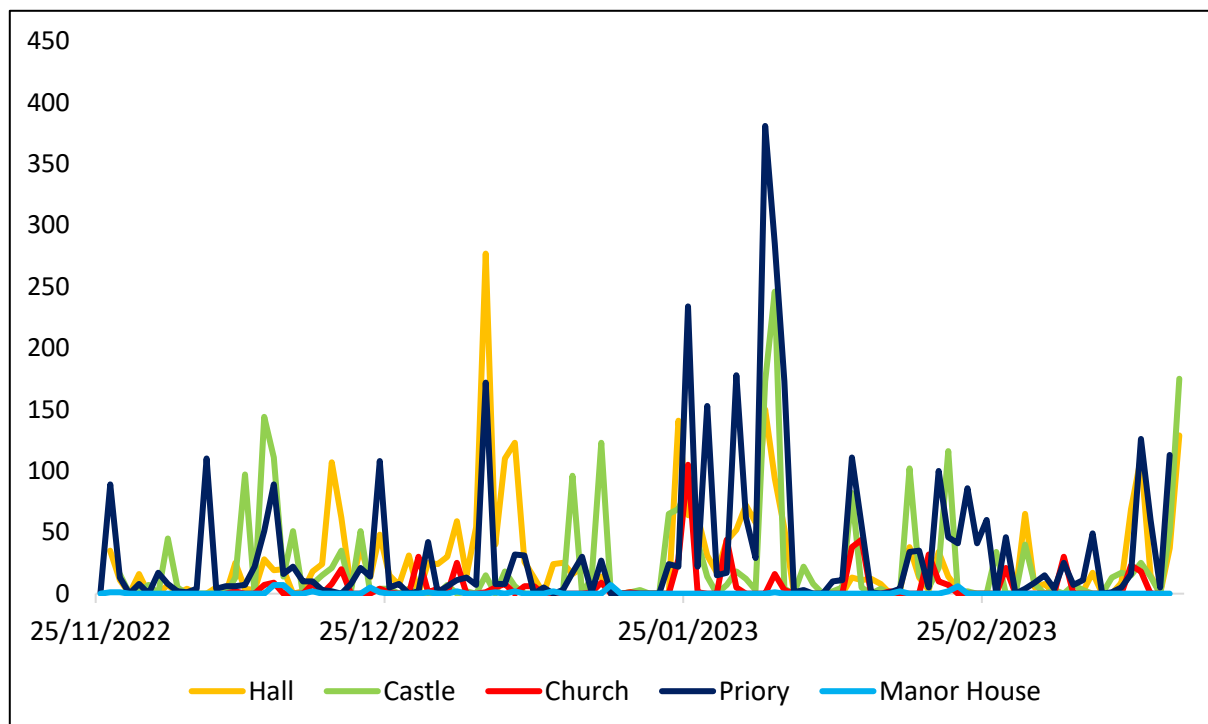


Figure 6: All *Pipistrellus* bat passes, 25th of November 2022 to 17th of March 2023.

England – North East

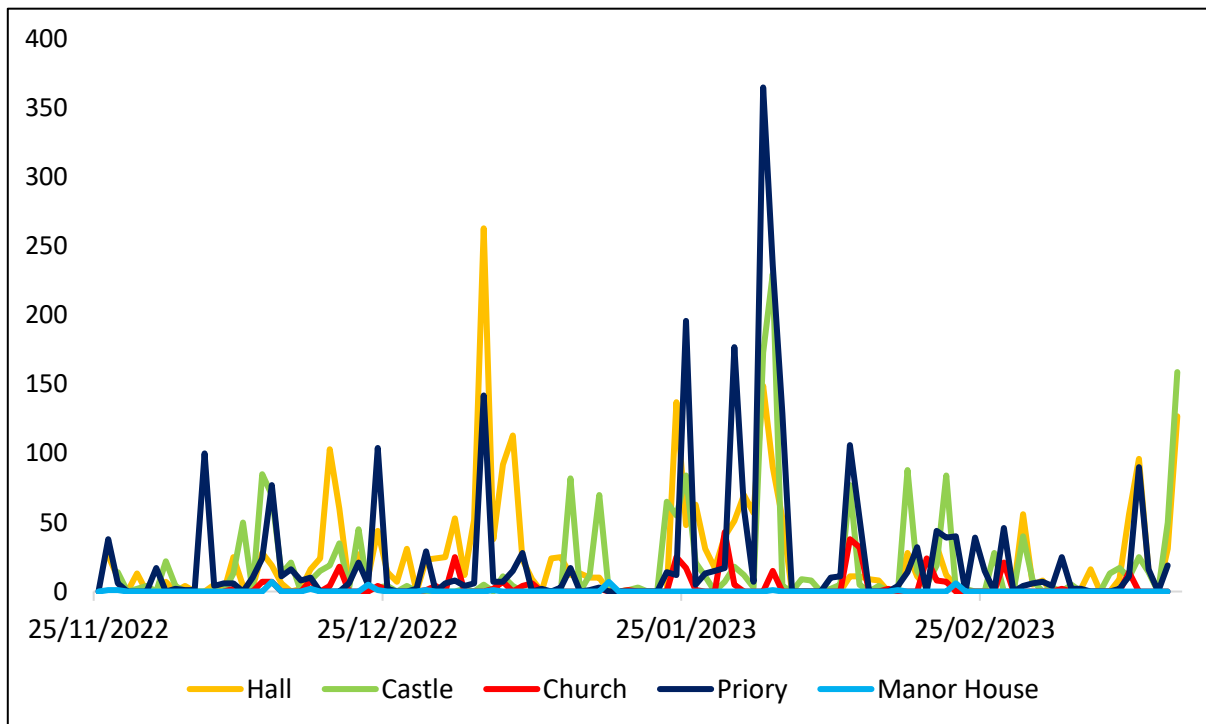


Figure 7: Common pipistrelle bat passes, 25th of November 2022 to 17th of March 2023.

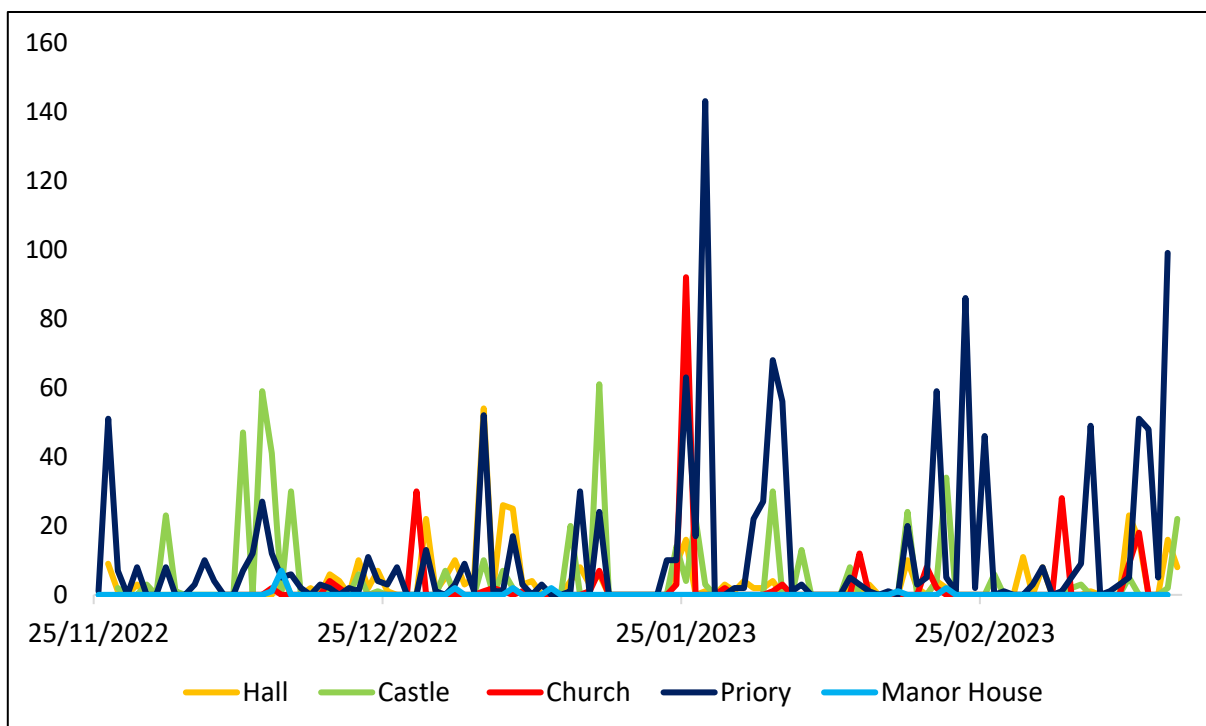


Figure 8: Soprano pipistrelle bat passes, 25th of November 2022 to 17th of March 2023.

Figure 9 suggests a relationship between low temperatures and an increase in the number of bat passes in December and early January. Simon *et al.* (2004) recorded bats entering hibernacula in November and December in relation to temperatures dropping below freezing. Bat activity in the Northumberland hibernacula rose in the first week of January after a mean temperature drop from 4.8°C to 0°C; low temperatures are related to winter roost switching by common pipistrelle (Simon and Sendor, 2003). After the beginning of

February, the relationship between temperature and bat passes changes, with bats becoming more active in higher temperatures, Avery (1985) found that *Pipistrellus* bats will feed in every month of winter on favourable nights with bat activity related to the temperature at dusk.

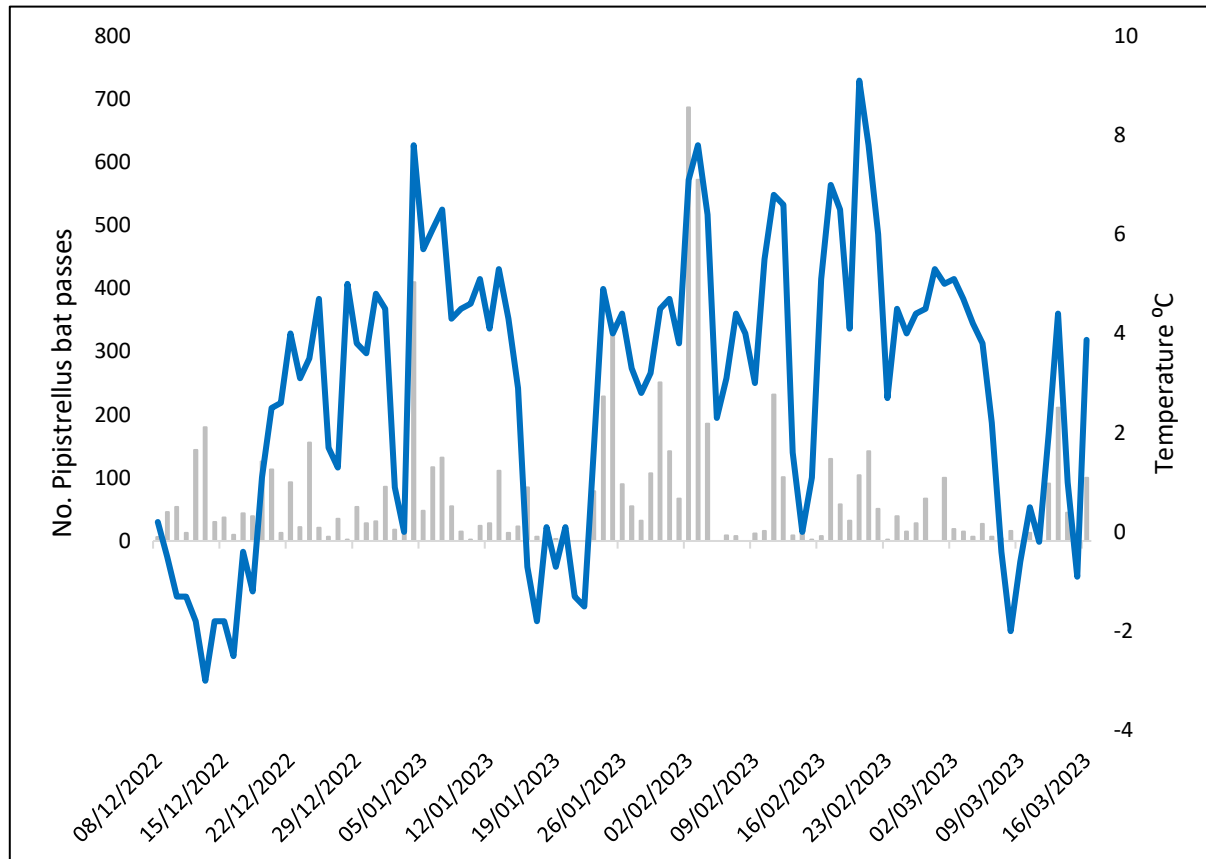


Figure 9: Total daily number of *Pipistrellus* bat passes recorded across all five sites and the corresponding mean minimum external temperature.

The relationship between low temperatures and an increase in the number of bat passes in December and early January can also be seen when considering sites individually. The hall and the priory were the sites with the highest levels of bat activity recorded, with a total of 2914 and 3818 *Pipistrellus* bat passes respectively. The priory recorded the highest number of bat passes in one night with 381 bat passes recorded on 2nd February 2023 and the hall recorded the second highest number, 277 on 4th January 2023 (Figures 10 and 11).

These figures are notable as the visual count data recorded a maximum of 70 bats in the hall in January 2023 and a maximum of only 17 bats in the priory in March 2023, less than 25% of the number of bats found in the hall (Figure 5). Despite the disparity in number of bats counted visually the priory recorded more bat passes overall and on a single night than the hall. This strongly suggests that visual surveys do not find all the bats present and that the variation in the percentage of bats found between sites can be large. This corresponds with previous studies, Jansen *et al.* (2104) estimated the percentage of visible bats in hibernation ranged from 22% to 90% in limestone quarries, whereas visual counts of around 500 common pipistrelle in a hibernaculum increased to over 5,000 individuals when an automated entrance counter was used (Korsten *et al.*, 2016).

England – North East

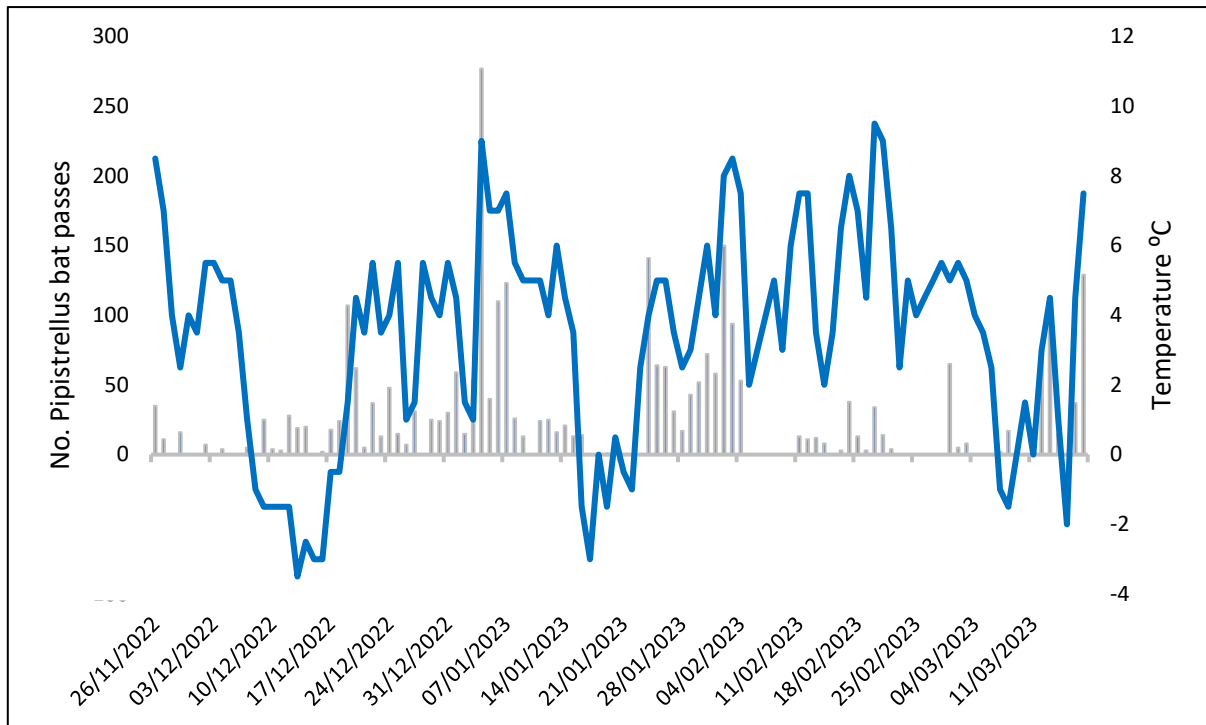


Figure 10: Total number of *Pipistrellus* bat passes recorded across in the hall per night and the corresponding minimum external temperature.

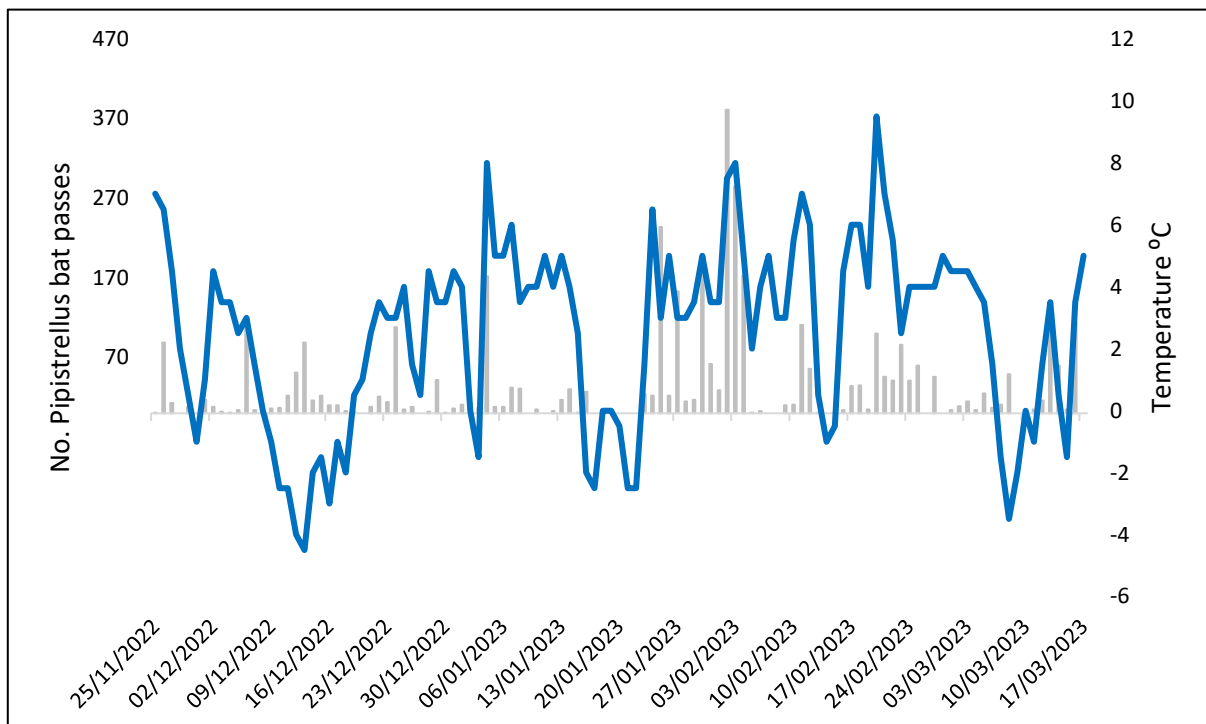


Figure 11: Total number of *Pipistrellus* bat passes recorded across in the priory per night and the corresponding minimum external temperature.

Conclusions

The acoustic data was collected on every day of the study period and, unlike visual hibernation counts, was not subject to observational bias. Acoustic monitoring could be developed into a methodology to find and monitor mass *Pipistrellus* hibernacula. Ideally,

acoustic data should be collected from the start of November, or even October, to cover the start of the period when bats begin to move to hibernacula.

It is important to find and record these above ground sites to ensure protection for *Pipistrellus* bats during the winter period. *Pipistrellus* hibernacula, especially mass hibernacula, are relatively unknown in the UK. The National Bat Monitoring Programme (NBMP) Hibernation Count data set has data for only 21 sites with more than ten hibernating *Pipistrellus* bats (Bat Conservation Trust, 2023).

These sites are relatively easy to find, so please get out there and get looking!

Acknowledgements

There are so many people who have been part of this project and whom I could not have done this without, however special mentions go to: the National Trust, English Heritage and the Church of England for patiently unlocking and locking sites for us and hosting AudioMoths for months; to Martyn Cooke at SonoBat for updating SonoBat to process AudioMoth files, twice; to Neil Tomas for taking photographs of very challenging bats and to the Reiver's Bat Research Group, you know who you are, for company, laughter, bat finding and cake.

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Are Nathusius' pipistrelle hibernating in Northumberland?

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I have been undertaking bat hibernation surveys as part of Bat Conservations Trust's (BCT) National Bat Monitoring Programme (NBMP) since 2011. Of the sites I monitor 23 are used by hibernating *Pipistrellus* species. Three of these sites regularly hold over 50 bats, the three largest known *Pipistrellus* hibernacula in the country (Briggs, 2023, pers. comm.). I survey these sites from November to March each year and so I am very familiar with both common pipistrelle *P. pipistrellus* and soprano pipistrelle *P. pygmaeus* in hibernation.

Hibernation surveys

On 27th November 2022, in a castle, I recorded a *Pipistrellus* bat deep in a crevice, 4.20m from ground level, which had pale ventral fur. Visibility of this bat was challenging and I was not able to obtain a clear photograph of the individual.

In February 2023 I recorded *Pipistrellus* bats with pale ventral fur at two different sites.

On 6th February 2023 I encountered a *Pipistrellus* bat in a church, this bat could be clearly seen with binoculars and was photographed by Neil Tomas (Figure 1).



Figure 1: Probable Nathusius' pipistrelle *P. nathusii*, 6th February 2023. © Neil Tomas.

A second *Pipistrellus* bat with paler ventral fur was recorded in a narrow crevice at a different site, a hall, on 16th February 2023. As was the case with the November bat, this bat was deep in a crevice and no clear photograph was obtained.

If confirmed these would be the first definite hibernation records for this species for these Northumberland sites; there are currently very few Nathusius' pipistrelle hibernation records for the UK (P. Briggs, 2023, pers. comm.).

Using binoculars and a torch it was possible to get good views of the bat in the church. This particular bat stood out as different; it was chunky, the forearm was substantial, the base of

the ear was broad, the nose shape was different and there was paler ventral fur visible (Deitz and Keifer, 2016).

Common and soprano pipistrelle were present in the same location on 6th February 2023. At least ten soprano pipistrelle were in the same crevice as the probable Nathusius' pipistrelle (Figure 2) and a common pipistrelle was recorded in the equivalent crevice to the east side of the roof (Figure 3).



Figure 2: Soprano pipistrelle, 6th February 2023. © Neil Tomas.



Figure 3: Common pipistrelle, 6th February 2023. © Neil Tomas.

I have recorded individual bats with pale ventral fur in hibernation in this church before, on 27th January 2016 and 22nd January 2018, but this is the first time it was possible to obtain a clear photo, as the bats are c.8m up and c.150mm deep in a gap between the stonework and a rafter.

Acoustic surveys

AudioMoth full-spectrum acoustic loggers were used to record bat activity in five sites in Northumberland during winter 2022-23; the sites where probable *Nathusius'* pipistrelle were seen were included in the acoustic surveys. The AudioMoths were configured to record at 192kHz with medium gain, recording continuously into eight-second sound files (Somerset Bat Group, 2020). The AudioMoths were set to record continuously for 120 minutes during the second and third hour after sunset (Jansen *et al.*, 2022).

SonoBat 30.0 was used to analyse the bat echolocation calls, noise files were removed and sound files with bat tonal features were analysed automatically using SonoBatch Classifier, UK Middle. Following this classification, SonoVet was used to manually verify the call classification with *Pipistrellus* calls identified to species level.

Low frequency *Pipistrellus* echolocation calls were recorded at two sites.

In the church the bats are hibernating in a small, enclosed area with bat access into the main church via a glass panel, it is considered that any calls recorded beneath the hibernacula will be those of bats in clutter and are likely to be higher than 40kHz. However, one clear pulse below 40kHz was recorded at this site on 24th January 2023 (Figure 4).

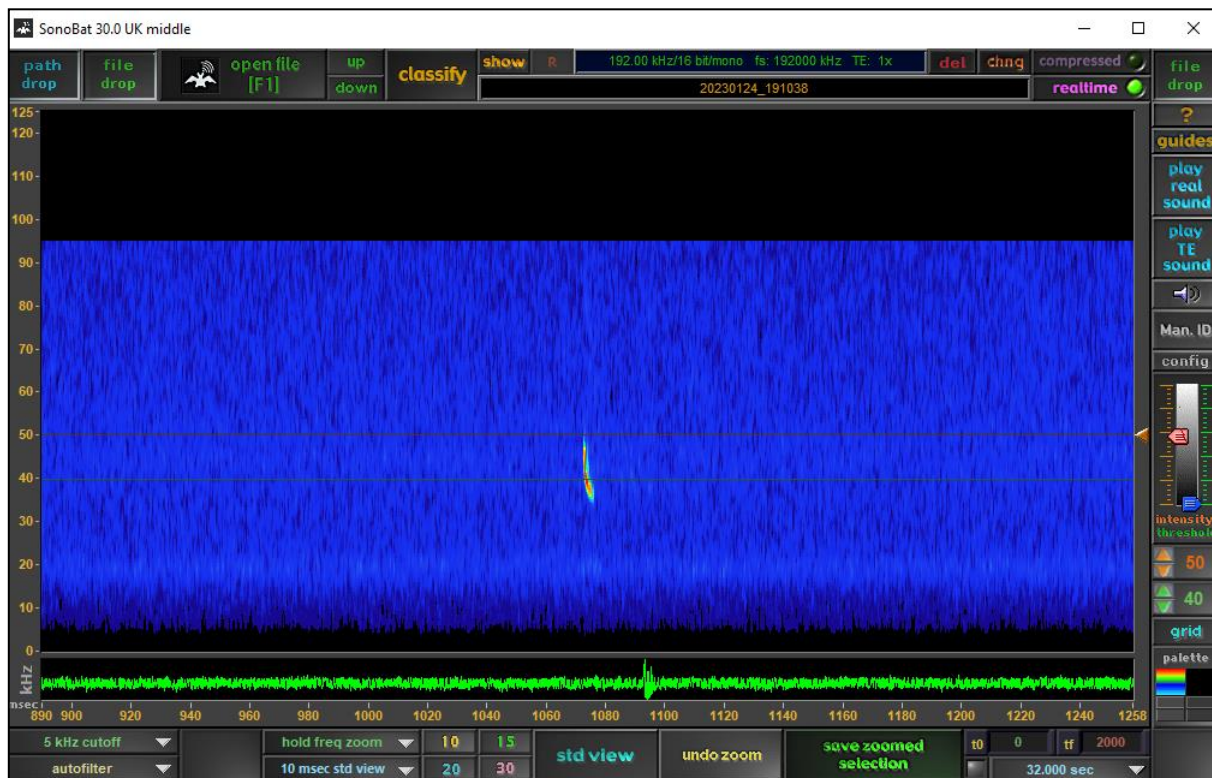


Figure 4: A single bat echolocation pulse below 40kHz, no other pulses were recorded in this sound file, 24th January 2023, church.

Low calling bats were also recorded at the castle, with a string of three files recorded on 26th February 2023. This site is more open, with bats recorded hibernating in a number of locations within the building, the detectors were placed in the same room as that in which the bat with paler ventral fur was seen in November (Figure 5).

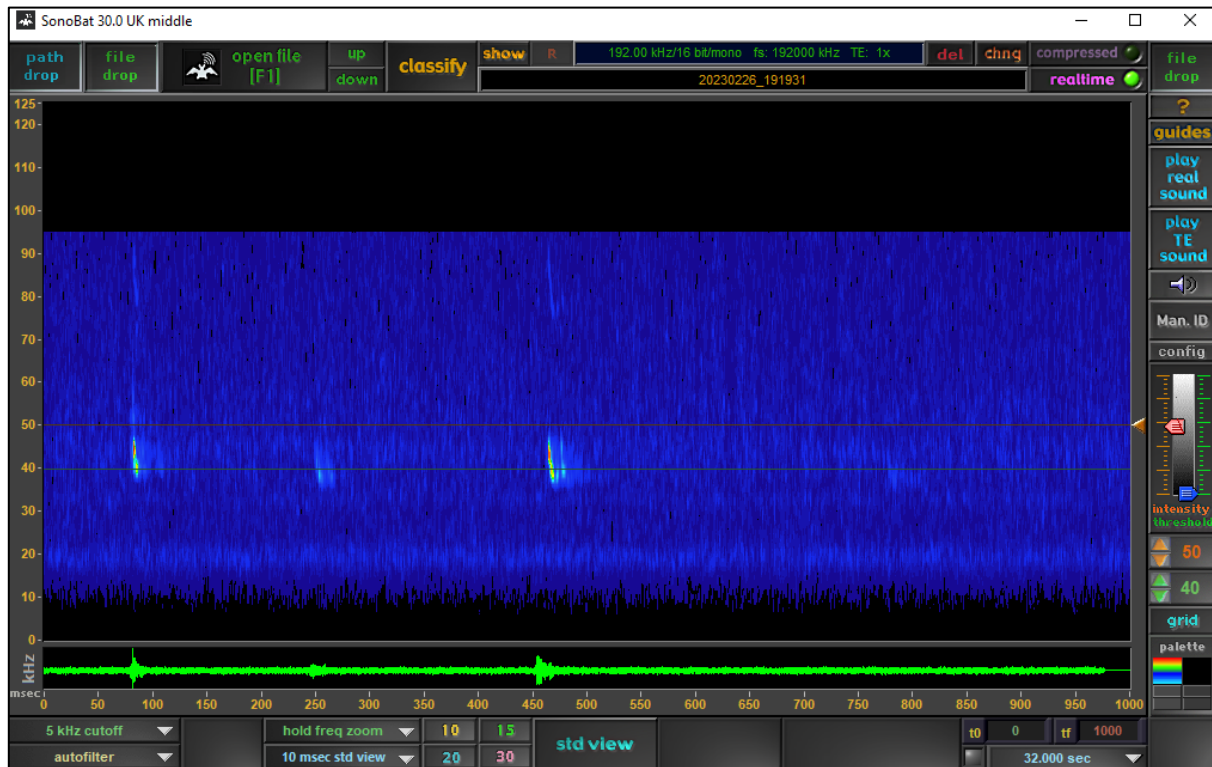


Figure 5: Bat echolocation pulses below 40kHz, 26th February 2023, castle.

No low *Pipistrellus* calls were recorded in the hall, the third location where a bat with paler ventral fur was recorded. This is the largest of the sites and the bats roost throughout the building and as the detectors are in one section, it is possible that bat calls are under recorded in this site. Of course, it is also possible that there were no low calling bats present.

Local context

Church

In 2012, as part of BCT's National Nathusius' Pipistrelle Project (NNPP), emergence surveys were undertaken at this church and low calling *Pipistrellus* species bats were recorded emerging, with calls between 40 and 42kHz, with three bats noted on 29th May 2012 and one on 1st June 2012. Nathusius' pipistrelle have been recorded emerging at c.42kHz as part of a radio tracking study at Blagdon (D. Hargreaves, 2023, pers. comm.).

Castle

There are no previous records of Nathusius' pipistrelle for this building, however on 4th June 2012, again as part of NNPP, Nathusius' pipistrelle were recorded flying over the river within 300m of this site (Figure 6).



Figure 6: Nathusius' pipistrelle, 4th June 2012, within 300m of the castle. Recorded with a Pettersson D240x and an Edirol recorder.

Hall

Looking back at my records, I noted a *Pipistrellus* bat with a paler underside during the hall hibernation check on 7th March 2018, but subsequently dismissed the record due to lack of supporting evidence. A bat walk at this site, on 26th April 2019, recorded numerous 40kHz *Pipistrellus* calls and a Nathusius' pipistrelle call by the building at 21:52 (Figure 7).

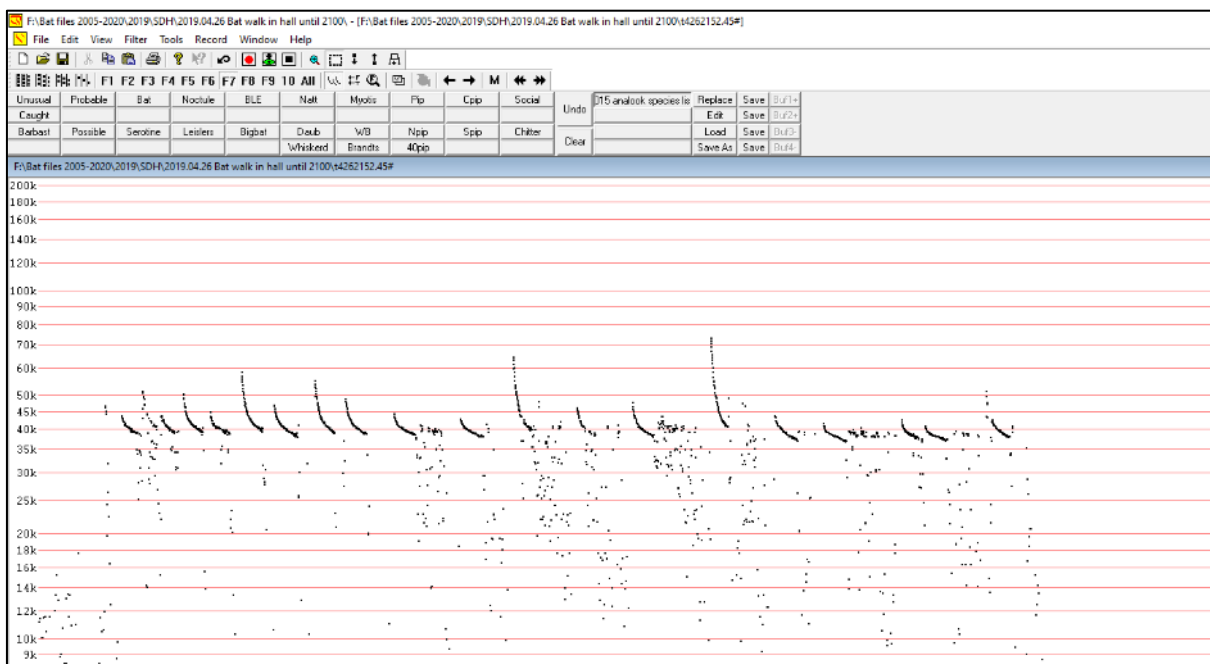


Figure 7: Nathusius' pipistrelle, 26th April 2019, hall. Recorded with an Anabat SD2.

Discussion

Nathusius' pipistrelle are known to be present in Northumberland, with the first confirmed flight record on 2nd May 2011, recorded by Hazel Makepeace, on the river Wansbeck at Ashington. This led to Northumberland Bat Group's involvement in BCT's NNPP, with Nathusius' pipistrelle recorded on seven co-ordinated National Bat Monitoring Programme Nathusius' Pipistrelle surveys in 2011 and the discovery of a maternity roost in 2016.

There is a lack of information for hibernating Nathusius' pipistrelle generally; they are known to hibernate in churches in Europe (D. Hargreaves, 2023, pers. comm.) and Dietz *et al.* (2009) report that Nathusius' pipistrelle prefer tree holes or rock crevices and that few hibernate in caves.

It is challenging to identify bats to species level when they are in high, inaccessible locations. The photograph in Figure 1 has been sent to a number of individuals for confirmation, with no overall consensus reached (so typical of bat workers!). However, from my experience of identifying bats in crevices I am convinced that this bat is a Nathusius' pipistrelle.

I consider it is highly likely that Nathusius' pipistrelle are hibernating in Northumberland. These bats are under recorded in winter due to the locations they choose to roost in. The records of Nathusius' pipistrelle presented here have only been found as a result of more intensive hibernation survey.

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The Impacts of Artificial Lighting on Bat Behaviour, Particularly Along Waterways

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Introduction

Artificial lighting at night (ALAN) is increasing due to the global rise in urbanised areas (McMahon *et al.*, 2022). The area of urbanised land around the world has doubled in the last 30 years (Bongaarts, 2019) and projections suggest that up to 68% of the world's population could be living in urban areas by 2050 (United Nations, 2018). Satellite analysis found that almost 90% of the land mass area of Europe and half of the US is affected by ALAN (Falchi *et al.*, 2016) and the more urbanised the area, the greater amount of ALAN it experiences. Although urbanisation and an increase in ALAN has been largely beneficial for humans and a selection of synanthropic generalist species which thrive in urban conditions (Concepcion *et al.*, 2015), it has negatively affected many others. Nocturnal species are particularly susceptible to detrimental effects from ALAN as they have spent many millennia adapting to survival in dark conditions at night. Disturbance from artificial light can impact their circadian rhythm, disrupt their foraging behaviour and increase their risk of predation (Rich and Longcore, 2006).

The second largest order of mammals is bats *Chiroptera* with more than 1,400 species globally, of which almost all exhibit a nocturnal lifestyle (Bat Conservation Trust, 2022). As a consequential adaptation, bats use echolocation to determine their surroundings and locate their prey under the cover of darkness, with the large majority emerging after sunset and roosting before sunrise. While research has been carried out worldwide in an attempt to determine what effects ALAN might be having on this nocturnal order, this review will focus on specific research which includes any of the 18 bat species found in the UK (Seewagen and Adams, 2021; Bat Conservation Trust, 2022).

All of the 18 UK bat species are obligate insectivores (Bat Conservation Trust, 2022). Because of this, their survival is highly linked to the availability and distribution of insects. It is evidenced that ALAN has the potential to impact bat species in differing ways (Voigt *et al.*, 2021), largely resultant of two theorised components. Firstly, some insects display photopositive behaviour towards lights, being attracted from the surrounding area. This results in a higher abundance of insects around the artificial light source due to the 'vacuum effect' exerted upon them (Russo *et al.*, 2019b; Stone *et al.*, 2015a). This attraction of insects towards lights provides a unique chance for resource exploitation for bats on a local scale in the form of increased feeding opportunity (Bolliger *et al.*, 2020; Russo *et al.*, 2019b). However, not all bat species take advantage of this, and instead avoid lit areas. It is suggested that this is because there is a greater perceived predation risk from predators such as owls or other avian raptor species (Jones and Rydell, 1994) in artificially lit areas compared to the darker alternative foraging locations. Thus, some bat species activity is decreased in artificially lit areas. The response of bats towards ALAN is typically linked to the flight speed and foraging style of the given bat species (Azam *et al.*, 2015; Azam *et al.*, 2016; Barre *et al.*, 2021), but responses can differ depending on lighting scenarios and spatial scales.

Methodology

Web of Science was used as the database to search for relevant information for this literature review. The first search included any published document including the words ('bat' and 'light' and 'artificial'). From this, there were 138 results. The titles were noted and unrelated research papers (such as research performed outside of the EU and on bat species not found in the UK) were deleted, bringing the search total to 69. These included all research into the effects of ALAN on bat behaviour near waterways. Following this, a further search was performed including any documents containing (((ALL=(bat)) AND ALL=(light)) AND ALL=(artificial)) AND ALL=(urban*)), with 53 results. The two searches were combined, and duplicates removed. After reading the titles and abstracts of the papers, irrelevant research was discarded. Exclusion criteria included studies not about bats, studies about bats located outside of Europe and studies in which the impact of ALAN was not directly relevant. This resulted in a final total of 44 journal articles and three review articles relevant to the impact of artificial light on bats in a range of different settings.

Larger Scale Impacts of ALAN (Habitat fragmentation)

ALAN can result in habitat fragmentation for bats through some species' aversion to lit areas. This is problematic as it can both prevent them from reaching their preferred insect-rich foraging locations and increase their energy expenditure by diverting to take longer, darker routes. Fragmentation caused by ALAN was demonstrated by Hale *et al.* (2015), with findings suggesting that bats would select the darkest paths to cross cities and that the use of brighter LED lights might threaten the accessibility of these darker crossing gaps utilised by the bats.

Laforge *et al.* (2019) findings further highlighted fragmentation by demonstrating that average irradiance is a key predictor of bat activity in urban environments and that a reduction in irradiance is an effective way to improve connectivity for bats within an urban setting. Additional evidence suggests that greater horseshoe bat *Rhinolophus hipposideros* and *Myotis* species significantly reduced their use of commuting routes when they were illuminated with ALAN, as well as reducing commuting along routes lit with 'low light levels' (Stone *et al.*, 2009; Stone *et al.*, 2012). Greater horseshoe bats were also found to quickly adapt to artificial lighting and switch to nearby, darker routes when they were available (Zeale *et al.*, 2018). While some studies found that ALAN did not result in fragmentation for some faster-flying species such as *Pipistrellus* species (Stone *et al.*, 2012; Straka *et al.*, 2019; Zeale *et al.*, 2018), larger-scale city and country-wide studies found stronger contradictory evidence suggesting even typically light tolerant bat species are negatively impacted by ALAN when on a larger spatial scale (Hale *et al.*, 2015; Lewanzik *et al.*, 2022; Mathews *et al.*, 2015; Pauwels *et al.*, 2019).

Despite some literature suggesting increased urban lighting may benefit some species, most agree that it has an overall negative impact on bats. These studies into habitat fragmentation highlight the importance of keeping dark corridors and vegetative areas in urban spaces (Mathews *et al.*, 2015) and especially alongside waterways. For species which predominantly feed along still waterways, such as Daubenton's bat *Myotis daubentonii*, large areas which are lit could be especially detrimental as there is a reduction of alternative areas for them to forage given their already narrowed niche. Implementation of dark corridors and keeping ALAN to a minimum along waterways in urban areas should be

recommended in order to reduce habitat fragmentation and enable and encourage commuting and foraging of all bat species.

Lighting type

On a more local scale, small adjustments to artificial lighting types have been demonstrated to alter bat behaviours. Kerbiriou *et al.* (2020), Lewanzik and Voigt (2017), Pauwels *et al.* (2021), Rowse *et al.* (2016), Stone *et al.* (2012) and Stone *et al.* (2015b) all carried out analysis on bat activity, defined as number of passes recorded against a point of interest, before and after conventional street lighting was switched to a newer, more energy efficient lighting type. Stone *et al.* (2012) also conducted a similar experiment prior to this, which was unique in using lit nights in comparison to dark, as control nights. While all had similar methods in comparing bat activity before and after lighting changes were made, they each investigated a unique combination of lighting-type change. The studies culminated in different findings regarding how bat species' activity levels changed (Table 2).

Despite each of these studies having robust methodologies and relatively large sample sizes, all except Rowse *et al.* (2016) and the re-analysis of the data by Kerbiriou *et al.* (2020), are limited because they all took place over a short period of time, ranging from three to eleven nights. None of them took into consideration the longer-term impacts of how the change in lighting type may affect the bat activity. Also, they neglected to sample at a diverse range of locations. Because of this, it is hard for the results to be extrapolated on a larger scale outside the local effects which were measured. Nonetheless, the results are not meaningless. Consistency between the findings show that majority of the species recorded were reported to have no change in their activity levels when the lighting type changed. This suggests that the overall response of most bat species towards ALAN is the same, regardless of what lighting type is used.

Lighting colour

Much like lighting type, lighting colour has also been investigated for its impacts on bat behaviour. It is theorised that if a lighting colour is found to have minimal impacts on bat behaviour, it should be considered as a possible replacement for typically used yellow and white lights to negate the negative effects of ALAN. Initial research into this topic was performed by Spoelstra *et al.* (2017), demonstrating that *Pipistrellus* species were equally as active under red light and darkness, while being significantly more active under white light and green light conditions in comparison to the control dark nights. *Myotis* and *Plecotus* species displayed negative responses to the green and white lit conditions and no change in activity level between the dark control night and red lit nights. It was suggested from this that red light may reduce the negative effects caused by ALAN. Zeale *et al.* (2018) later demonstrated that red light significantly reduced the activity of a differing species, greater horseshoe bat, questioning the previous theory that red light does not negatively impact bat activity. Also investigated were orange, white and green light, with *Pipistrellus* species being more active and *Myotis* species being significantly less active in all lit conditions in comparison to dark control nights. The findings demonstrate the unique responses from different bat species towards ALAN and suggest that there is no lighting colour which does not have detrimental effects on at least one bat species' activity.

Table 2: A summary of the findings from research into the different effects street lighting has on bats (Kerbiriou *et al.*, 2020; Lewanzik and Voigt, 2017; Pauwels *et al.*, 2021; Rowse *et al.*, 2016; Stone *et al.*, 2012; Stone *et al.*, 2015b). Energy inefficient lighting types include high-pressure mercury vapour (MV) lamps, low-pressure sodium (LPS) lamps and high-pressure sodium vapour (HPS) lamps. Newer, more energy efficient lighting includes light-emitting diode (LED) lamps and white metal halide/high intensity discharge (HID) lamps.

Researcher	Comparison	Bats which increased activity levels	Bats which decreased activity levels	Bats which did not change activity levels
Stone <i>et al.</i> , (2012)	Dark nights to LED nights.	None.	Greater horseshoe bat and <i>Myotis</i> species activity decreased when LED lights were on.	Common pipistrelle <i>Pipistrellus pipistrellus</i> , soprano pipistrelle <i>P. pygmaeus</i> , <i>Nyctalus</i> and <i>Eptesicus</i> species.
Stone <i>et al.</i> , (2015b)	LPS to HID.	Common pipistrelle showed significantly more activity under HID than LPS lights.	None.	All recorded species except common pipistrelle.
Pauwels <i>et al.</i> , (2021)	HPS to LED.	None.	Savi's pipistrelle <i>Hypsugo savii</i> (not a UK species).	All other species recorded.
Lewanzik and Voigt, (2017)	MV to LED.	<i>Myotis</i> species increased 4.5 times when MV was changed to LED.	Common pipistrelle activity decreased by 45% when switched to LED.	Soprano pipistrelle and <i>Nyctalus</i> and <i>Eptesicus</i> species.
Rowse <i>et al.</i> , (2016)	LPS to LED	None.	None.	All.
Kerbiriou <i>et al.</i> , (2020)	LPS to LED.	Common pipistrelle and <i>Nyctalus</i> species showed significantly more activity under LED than LPS lights.	None.	Soprano pipistrelle.

Contrasting this, Spoelstra *et al.* (2018) investigated the effects of coloured lights by artificially lighting culverts found along the commuting path of Daubenton's bats with red, white and green light. In comparison to the dark control nights, there was no effect of lighting, regardless of the colour, on bat activity levels. Furthermore, the bats also showed no preference or aversion to any colour used. While this has positive implications in suggesting coloured lights could be used as an alternative solution without impacting water specialist bat behaviours, it is limited in its relevance as passing through culverts is a niche situation and does not reflect coloured lighting along larger scale commuting routes or foraging locations, particularly in relation to waterways.

Each of these pieces of research were carried out with different experimental set-ups and in different locations around Europe. For example, Zeale *et al.* (2018) lit up alternate sides of hedgerows in England, while Spoelstra *et al.* (2017) used light posts in a range of forested and non-forested locations in the Netherlands and as previously discussed, Spoelstra *et al.* (2018) lit culverts along bats' commuting pathway, also in the Netherlands. The differences in methodologies and locations may be a reason contradictory results were found. This suggests that generalisation of findings should be done with caution, as findings may differ between locations and experimental design.

Feeding and Drinking

As demonstrated above, even small adjustments such as the change in lighting type and colour can have a significant impact on bat activity levels. It is therefore unsurprising that changes to lighting also alter other aspects of bat behaviours, including foraging and drinking. Bats have high metabolic rates when active (Munshi-South and Wilkinson, 2010) and require food almost immediately after emergence. Kerbiriou *et al.* (2020) found that the common pipistrelle feeding buzzes recorded around LED lights were higher than in comparison to LPS lamps. While this aids in distinguishing the effects different lighting types can have, there is no comparison to dark control nights, and the information can only explain the relative difference between the two lighting types. Alternate findings suggest that common pipistrelle feeding buzzes decrease in lit sites. Barre *et al.* (2021) investigated the impacts of bat behaviour around artificially lit bridges and only recorded common pipistrelle feeding buzzes at the unlit sites. However, this was not the focus of the research and other extraneous variables not accounted for might have affected bat feeding behaviours, such as noise pollution and human activity.

Little attention has been paid into direct measurement of feeding activity and many assumptions regarding this topic are drawn from bat activity levels instead, as discussed through the duration of this review.

The effects of ALAN on drinking behaviour remains a relatively understudied area, with potential for further investigation. Russo *et al.* (2017) demonstrated overall bat drinking activity decreased in lit areas, with only light-tolerant species displaying an increase in drinking behaviours. Their methodology included artificially lighting two identical cattle troughs and comparisons of drinking behaviours were made between the lit nights and dark control nights. A later study performed by Russo *et al.* (2019a) found similar results, with common methodological elements to the previous study. Six identical cattle troughs in different locations were artificially illuminated and bat drinking activity was analysed. As

with the previous research, common pipistrelle drinking activity increased. However, this time the increase was not significant. Furthermore, barbastelle *Barbastella barbastellus*, *Plecotus* species and *Myotis* species were all found to significantly decrease drinking in response to the artificial light. While these two experiments are pioneering within this area of research, they are not without constraints. For example, the majority of drinking activity occurs on larger waterbodies, where ALAN is unlikely to affect the whole water surface, thus unlit areas suitable for drinking would still remain. The limited number of study sites also hinders the generalisation of the findings.

ALAN along Waterways

There is little direct research into the impacts of ALAN on bat behaviour near waterways. Only two papers could be found assessing the impacts of ALAN within this topic area. The first by Russo *et al.* (2019b) demonstrated that LED-lit sites along a river in Italy experienced an overall decrease in bat activity, mostly attributed by the decline in water-specialist *Myotis* species such as Daubenton's bat which are normally the most abundant species found along waterways (Richardson, 2002). This decrease was measured despite an increase in the numbers of insects found at the site. The research was performed in rural Italy, so the results may not be the same as if the research was carried out in the UK and may also differ to how ALAN may impact behaviours in urban settings. Replication of the research over different locations and years is recommended to verify these findings. The second, by Barre *et al.* (2021), found corroborating results in that bat activity was 1.7 times lower past bridges which were artificially lit, in addition to finding that soprano pipistrelle bats flew past lit bridges faster and at a greater distance to the unlit bridges. This study had a small sample size of six bridges and was performed in France, where again the results may differ to the UK. It also was undertaken in highly urbanised areas, where confounding variables other than light, such as traffic levels and noise disturbance, may also have impacted the results. These factors were not accounted for in the analysis of the study's findings. While there are limitations to the research, both papers successfully demonstrate that ALAN has a negative impact on those bat species which forage around waterways and that artificial lighting should be kept to a minimum to least disturb bat behaviour. There is nonetheless a large gap in research regarding the impact of ALAN next to waterways and especially research on bats in the UK as they may have differing responses. This provides large potential for further investigations into the impacts of ALAN along waterways, particularly longitudinal studies following the patterns of behaviour seen over time.

Conclusion

This review on the impact of ALAN on bat behaviour is unique in focusing on waterways. As there is a limited amount of research performed in this field, conclusive results of bat behaviour around ALAN on waterways are difficult to attain. Because of this, an understanding of how ALAN impacts bats in other settings is fundamental to hypothesising how it might affect bat behaviour along waterways.

Larger-scale studies of the impacts of ALAN suggest that artificial lighting can cause habitat fragmentation and reduce connectivity for bats. Smaller-scale research highlights how sensitive bats are to changes in ALAN, such as through lighting type and colour. Research also demonstrates how ALAN can be detrimental to the feeding and drinking behaviours of bats, a fundamental and imperative element to their survival. While research frequently

concludes in contradictory findings, these can be explained by the subtle differences in the unique experimental set-ups of each piece of research. It is thus advised that results should be considered within the context of their situation before generalised assumptions of behaviour are made. However, there is a consensus between all the research that regardless of contradictory findings, ALAN, whatever context it is within, nearly always negatively impacts at least one bat species. Therefore, it is concluded that recommendation of keeping ALAN to a minimum is most beneficial to the overall prosperity of the species.

There is insufficient research into the longitudinal effects of ALAN on bats, as well as limited larger-scale research projects onto the effects of ALAN along waterways. Longitudinal and wide-scale research provides a more detailed exploration of bat behaviour changes and allows for consideration of adaptations, unlike other short-term studies which provide results of a snapshot of time. Because of this, combined with the lack of research onto the effects which ALAN causes on bat behaviour at waterways, it is recommended that research into this novel, complex and specific area is performed.

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First Motus tag results from Bedfont Lakes study of Nathusius' pipistrelle

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Introduction

Nathusius' pipistrelle *Pipistrellus nathusii* is found from western Europe to Asia Minor (Corbet and Harris, 1991; Strelkov, 1997a, b; Mitchell-Jones *et al.*, 1999) and was first recorded in Great Britain in Walsay in the Shetland Islands in 1940 (Hermann, 1992). Since then records have been infrequent and, as a result, the species was initially regarded as a vagrant. By 2001, British records had increased to 91 (Russ *et al.*, 2001). To date, the Bat Conservation Trust has recorded 2,761 Nathusius' pipistrelles as part of their National Nathusius' Monitoring Programme (Packham, 2023, pers. comm.).

Whilst Nathusius' pipistrelle is known to breed at a number of locations within the British Isles it has also been well documented as a migratory species on the European Mainland. Movements are known to take place in a north-easterly direction in spring from Iberia to the Baltic Regions to breed (Aellen, 1983) and vice versa in autumn (Strelkov, 1969). However Nathusius' pipistrelle movements in and out of the UK and their migration routes and origins are poorly understood. The species is often found at large waterbodies (Lundy *et al.*, 2010), particularly during its autumn migration period (Russ *et al.*, 2001).

Bedfont Lakes Country Park is a reclaimed gravel pit and landfill site just south of Heathrow airport, London, UK. Nathusius' pipistrelles were first recorded at this location in 2002.

A number of bat boxes had been erected on trees in an area of wet woodland adjacent to water bodies. Soprano pipistrelles *P. pygmaeus*, common pipistrelles *P. pipistrellus*, Daubenton's bat *Myotis daubentonii* and whiskered bat *M. mystacinus* have also been recorded at the site. The boxes have been regularly monitored since 2002 and Nathusius' pipistrelles are regularly found in spring and autumn but not in summer.

As a result of these bat box checks, which demonstrated consistent use of the site by Nathusius' pipistrelles, a targeted project was established to study them further with a ringing and trapping licence from Natural England granted in 2012.

In 2014, the Bat Conservation Trust (2023) also implemented a targeted survey of Nathusius' pipistrelles, using trapping, ringing, radio tracking and stable isotope analysis from fur samples to provide more detailed information on this species' distribution and breeding status in the UK and Europe, as well as migratory movements between the UK and mainland Europe.

At Bedfont a total of 138 Nathusius' pipistrelles have been ringed between 2012 and 2023; 60 male and 78 females. As this is a migratory species recaptures will continue to provide valuable new information. In 2021 a Nathusius' pipistrelle ringed at Bedfont in 2016 flew the longest migration distance of a Nathusius' bat from the UK then known, travelling 2018km to Russia (Briggs, 2022).

Discovering more about the migratory activity of Nathusius' pipistrelles in the UK will contribute to the overall understanding of migration across its distribution. Nathusius' pipistrelle has been identified to be at high risk of mortality from wind turbines in Europe which have the potential to negatively impact upon bat populations (Bach *et al.*, 2022).

The Motus Wildlife Tracking System¹ is now being used to gather migration and other data. Unlike radio tracking using 173kHz VHF tags, in Europe the Motus system using 150.1MHz allows a much greater range of temporal and geographical information to be gathered about movements of individuals, using a network of receiving stations (Figure 1).

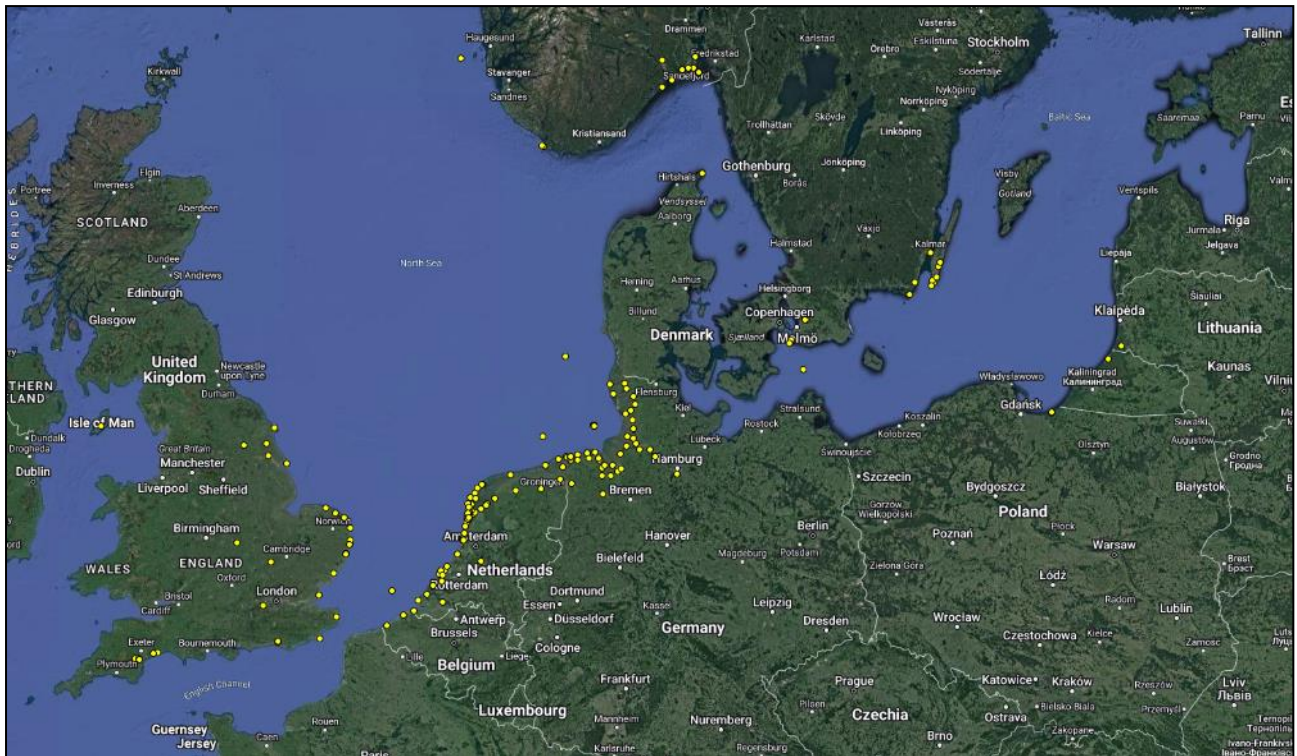


Figure 1: Distribution of Motus Receivers (Birds Canada, 2023a).

Motus is an international collaborative research network that uses coordinated automated radio telemetry to facilitate research and education on the ecology and conservation of migratory animals (birds, bats and insects). Motus is a program of Birds Canada in partnership with collaborating researchers and organisations.

In 2021, funding was secured to install a Motus Receiver (Birds Canada, 2023a) at Bedfont Lakes Country Park and this was erected on the Visitors' Centre in 2023 (Figure 2, left). The receiving station at Bedfont Lakes was fitted with three aerials. It was not possible to fit a fourth as the existing security camera was in the way. The potential coverage by the Bedfont Lakes receiver is shown in the right of Figure 2.

¹ <https://motus.org/>

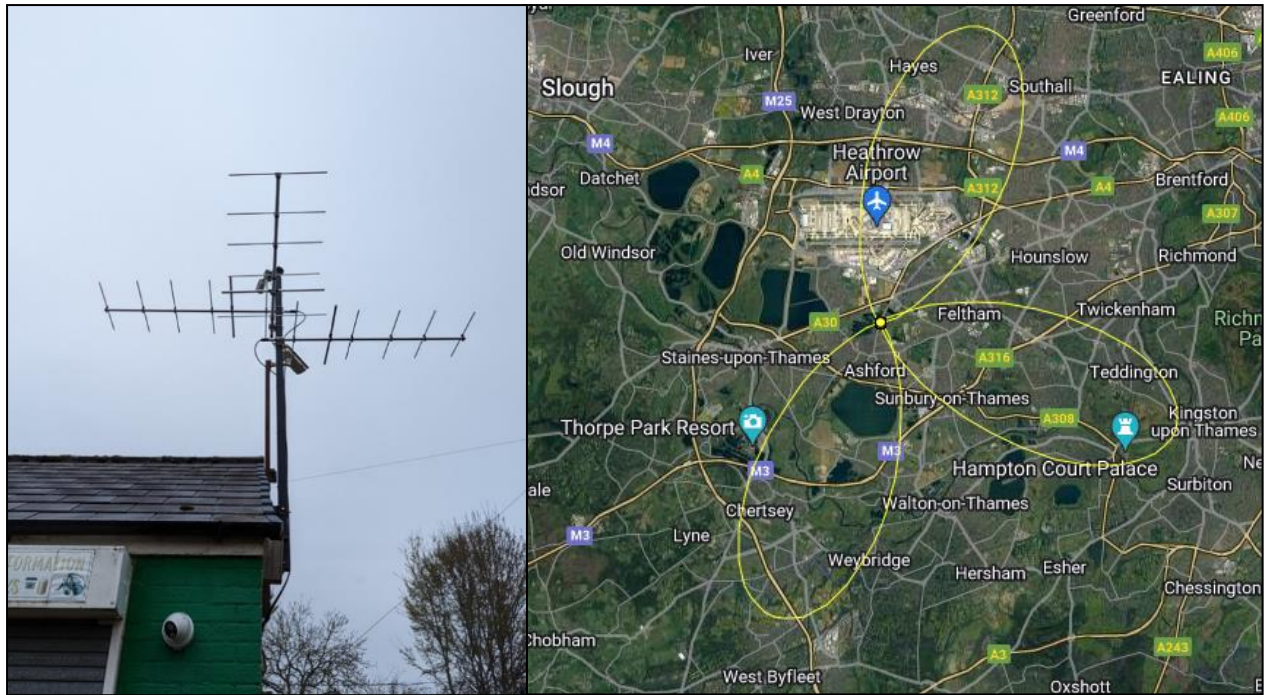


Figure 2: (left) installed MOTUS receiver at Bedfont Lakes, © S. Parsons and (right) potential coverage (Birds Canada, 2023b).

Ten Lotek VHF Nanotags (NTQB2-1; Figure 3) were purchased; weight 0.26g and available in pre-set burst intervals (pulse rate) from 2-40secs. Each has a unique code incorporated into the transmission which allows individuals to be identified using a Lotek SRX receiver. The lifespan of the radio tags depends on the weight of the battery and the rate at which pulses are transmitted.

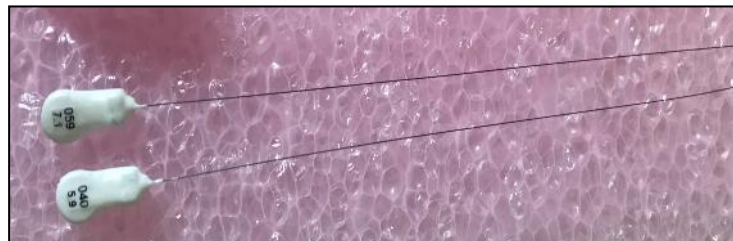


Figure 3: Lotek nanotag. © E. Parsons.

Wageningen Marine Research (WMR) in the Netherlands has been studying migratory activity of *Nathusius' pipistrelle* using a network of acoustic monitoring and Motus receivers with excellent results. Recorded activity levels indicated that the peak migration periods were April and September (Lagerveld *et al.*, 2019). Further work carried out in East Anglia using Motus nanotags confirmed that mid April to mid May is the peak of spring migration in the UK, mainly of females (Harris, 2022, pers. comm.). A tagging session was undertaken on 16th April 2023 at Bedfont Lakes to coincide with the spring migration period.

Results

Six female and two male *Nathusius' pipistrelles* were retrieved from bat boxes and three females from traps. Nine females and two males were tagged with the help of Jane Harris

who has experience of using the Motus system along the coast of East Anglia. All were safely released. Six of the tagged bats were only detected at Bedfont (Table 1).

Table 1: Six tagged bats were only detected at Bedfont (Birds Canada, 2023c).

Tag No. (sex)	Dates detected at Bedfont receiver
Tag 14 (♀)	16th April 2023
Tag 15 (♀)	16th, 17th and 30th April 2023
Tag 16 (♂)	16th, 17th, 18th, 23rd, 25th, 26th, 29th April, 2nd May and 3rd May 2023
Tag 91 (♂)	16th, 17th, 22nd and 26th April 2023
Tag 96 (♀)	16th and 17th April 2023 (previously ringed at Bedfont Lakes on 17th April 2022 from a bat box)
Tag 97 (♀)	16th, 19th April 2023

For the tags that dispersed from Bedfont Table 2 gives the number of nights each tag was detected at each receiver.

Table 2: Number of nights tags were detected at each receiver (Birds Canada, 2023c).

Receiver	Tag 17	Tag 92	Tag 94	Tag 95
Bedfont Lakes	6	3	7	1
BenacreNNR	-	-	-	1
Dungeness Bird Observatory	2	-	-	-
Emssperrwerk	-	-	1	-
Landguard Bird Observatory	-	-	1	-
Lowestoft - CEFAS	-	-	-	1
RUG Linnaeusborg	-	-	1	-
Sandwich Bay Bird Observatory	-	6	-	-
WUR - Oostvoorne	-	-	1	-
WUR Benacre Pump Station	-	-	-	1
WUR Brouwersdam sluis	-	-	1	-
WUR Dunwich	-	-	-	1
WUR Minsmere2	-	-	-	1

Tag 17 (♀) – Dungeness

The detections at Dungeness were spread over two nights but there were only 18 pings² in total. From the signal strength information it appears that the tag was a significant distance away from the receiver, potentially up to 4 or 5km.

The straight line distance between Bedfont and Dungeness is approximately 114km (Figure 4). The time between detections at Bedfont and Dungeness is over three days so it is not possible to estimate how fast the bat flew.

Interestingly, a male *Nathusius' pipistrelle* ringed at Dungeness on 30th September 2016 was found in a bat box at Bedfont Lakes on 10th September 2023 (Table 3). This is the second record of a move between Dungeness and Bedfont.

Table 3: Tag 17 first and last detections (Birds Canada, 2023c).

Receiver	First detection	Last detection
Bedfont Lakes	2023-04-17 01:57:49	2023-04-30 23:48:40
Dungeness Bird Observatory	2023-05-02 02:10:08	2023-05-04 21:04:45

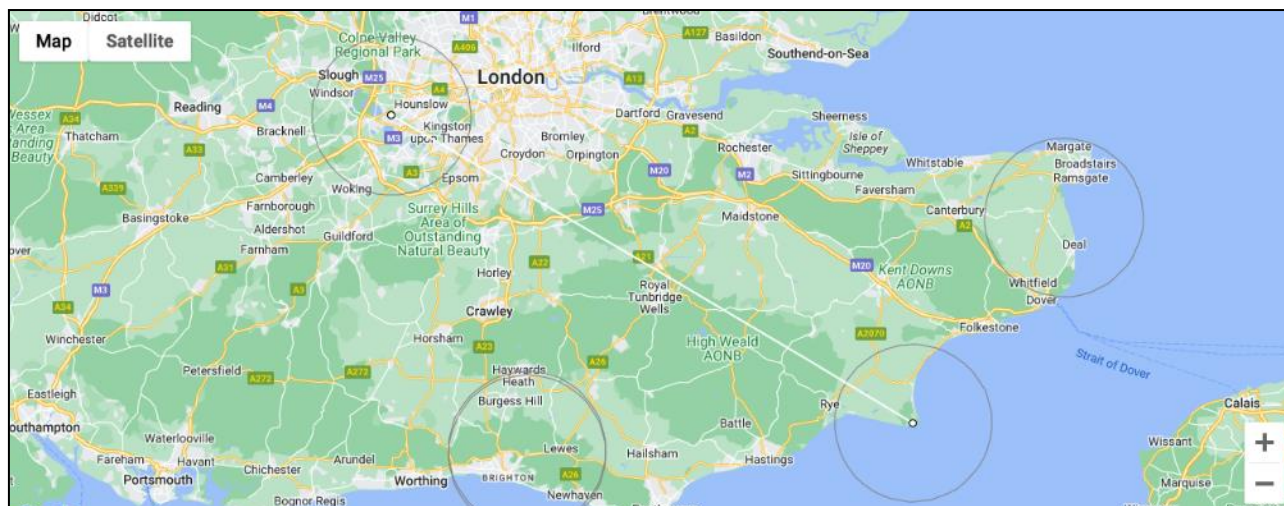


Figure 4: Tag 17 detections (Birds Canada, 2023c).

Tag: 92 (♀) – Sandwich Bay

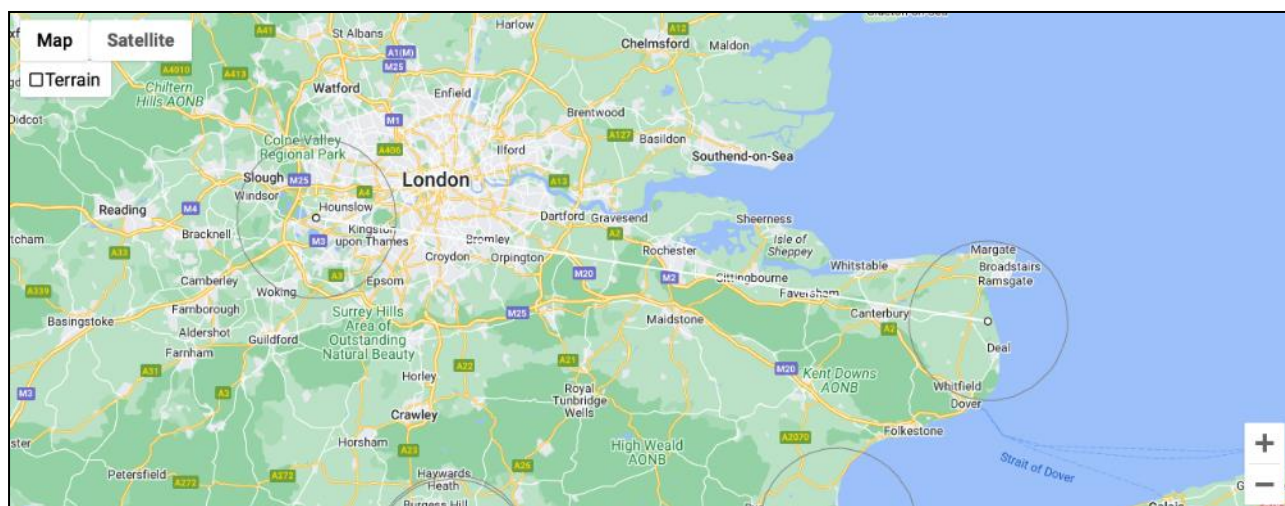
Tag 92 was detected at Sandwich Bay over nine nights (Table 4), with over 400 individual pings. The majority of detections were on antenna #2, which overlooks an extensive area of marshland towards the town of Deal.

The straight line distance between Bedfont and Sandwich Bay is approximately 128km (Figure 5). The time between detections at these two sites is approximately 26 hours. It is not possible to directly estimate flight speed as the bat would have roosted during daylight hours.

² A ping is where the Motus receiver picks up the acoustic pulse from the Lotek nanotag on a bat.

Table 4: Tag 92 first and last detections (Birds Canada, 2023c).

Receiver	First detection	Last detection
Bedfont Lakes	2023-04-16 17:53:26	2023-04-30 20:59:55
Sandwich Bay Bird Observatory	2023-05-01 22:47:01	2023-05-09 21:52:41

**Figure 5:** Tag 92 detections (Birds Canada, 2023b).**Tag 94 (♀) – East Anglia, Netherlands and Germany**

Tag 94 migrated furthest (Table 5). It had been ringed on 17th April 2022. She was found in a bat box on 16th April 2023 with a second female (tag 96) which had also been ringed on 17th April 2022 and an unringed male. It was detected at five other receivers beyond the tagging site at Bedfont (Figure 6).

Table 5: Tag 94 first and last detections (Birds Canada, 2023c).

Receiver	First detection	Last detection
Bedfont Lakes	2023-04-16 17:52:44	2023-04-28 19:53:49
Landguard Bird Observatory	2023-05-04 21:32:06	2023-05-04 21:37:05
WUR Brouwersdam sluis	2023-05-05 00:27:30	2023-05-05 00:37:39
WUR Oostvoorne	2023-05-05 00:34:08	2023-05-05 00:40:39
RUG Linnaeusborg	2023-05-05 23:41:13	2023-05-05 23:43:59
Emssperrwerk	2023-05-06 00:40:25	2023-05-06 01:04:39

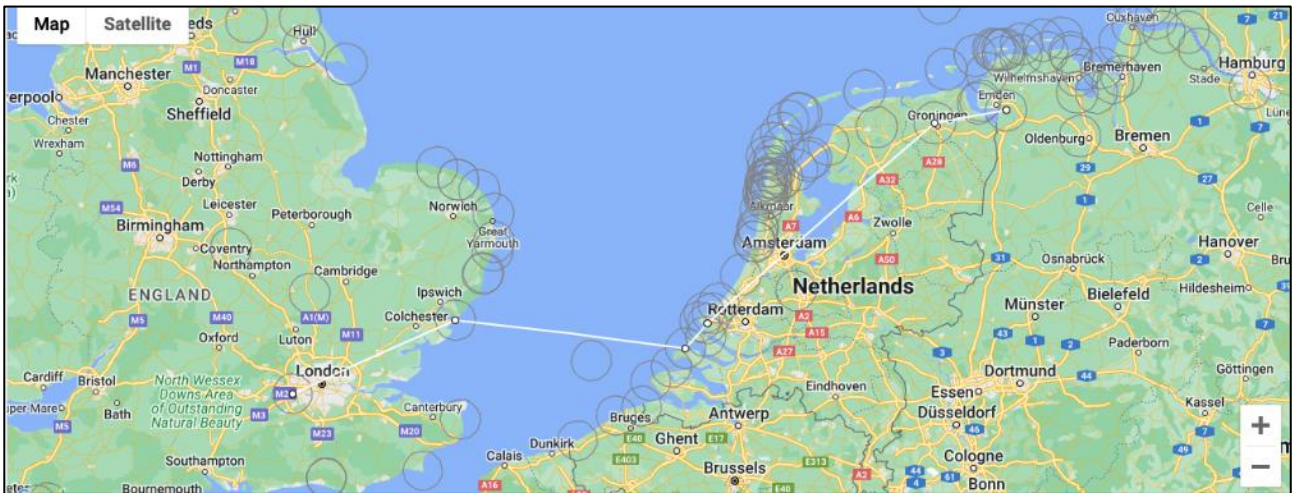


Figure 6: Tag 94 detections (Birds Canada, 2023b).

Landguard

After departing Bedfont the bat was next detected at Landguard near Felixstowe. The bat was only detected for 5 minutes but during this time 85 pings were recorded, most on the south facing antenna. The signal strength (Figure 7) showed a characteristic rise and fall indicative of a tag crossing the detection zone of an antenna.

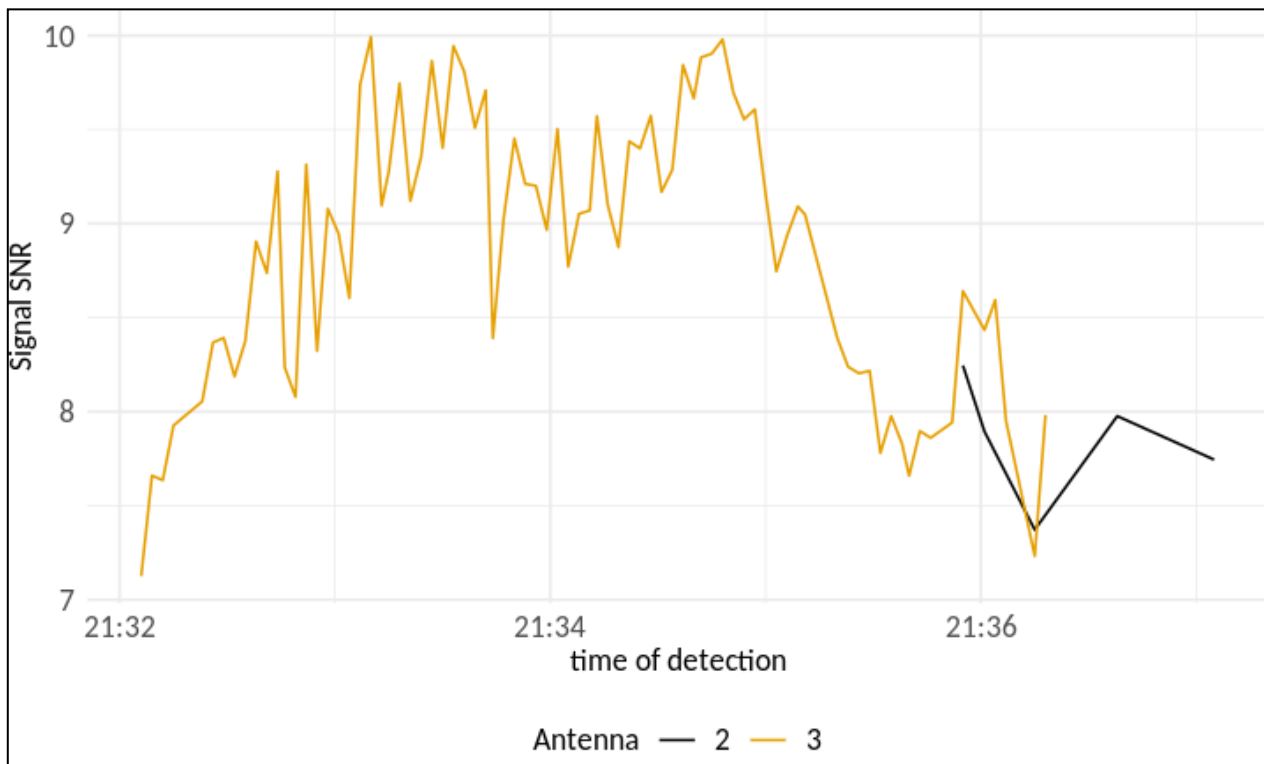


Figure 7: Tag 94 detected signal strength at Landguard receiver, UK (Birds Canada, 2023c).

Brouwersdam and Oostvoorne (Netherlands)

These receivers are located approximately 5km apart on the Dutch coast South of Rotterdam (Figure 8). Tag 94 was detected at these receivers approximately three hours after the detections at Landguard (Table 5). The detections at these receivers lasted approximately 15

minutes (Figure 9) during this time with over 120 pings. The distance from Landguard to Brouwersdam is over 170km and the estimated flight speed is over 60km/hr.



Figure 8: Map showing the locations of Brouwersdam and Oostvoorne receivers, Netherlands (Birds Canada, 2023b).

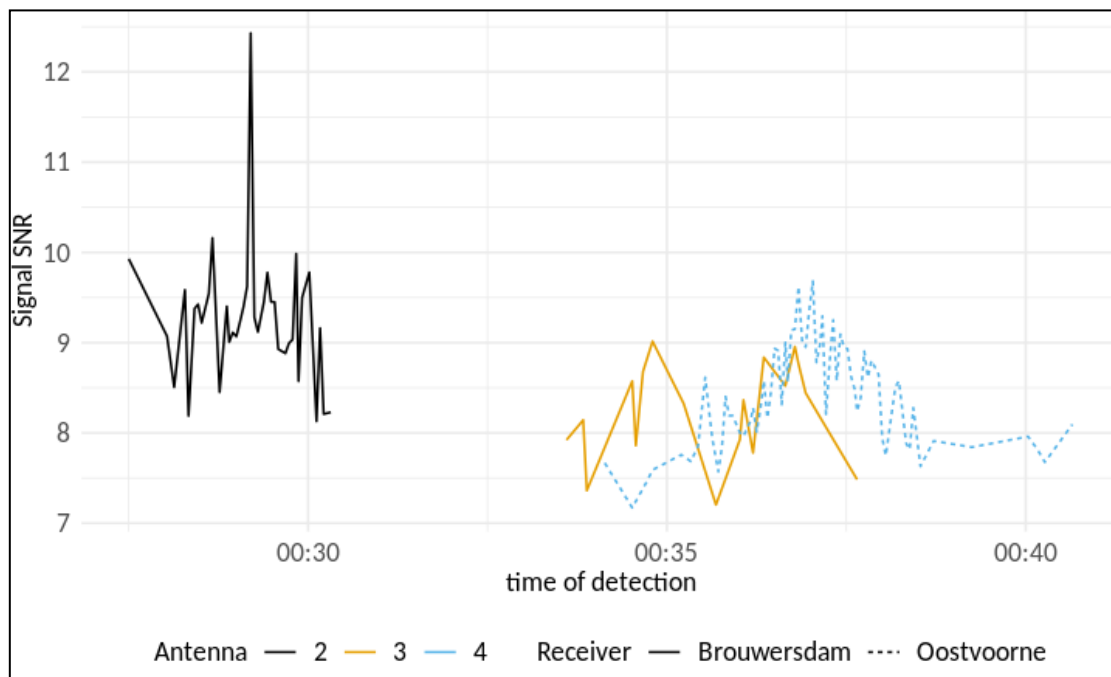


Figure 9: Tag 94 detected signal strength at Brouwersdam and Oostvoorne receivers, Netherlands (Birds Canada, 2023c).

Groningen Linnaeusborg (Netherlands)

The tag was detected at this receiver approximately 22 hours after the detections at Brouwersdam/ Oostvoorne. This receiver is located in the ground of the Groningen

University in the north of the Netherlands, and some 220km from the Brouwersdam/Oostvoorne receivers.

The tag was detected for two minutes with only eight pings. The signal strength is low so it is likely that the bat passed at some distance from the receiver. Further investigation is required to confirm if the detections at this receiver are genuine.

Emssperrwerk (Germany)

The tag was detected at this receiver approximately one hour after the detections at the Linnaeusborg receiver. The straight line distance between the receivers is approximately 50km so the likely flight speed is 50km/hr. The tag was detected at this receiver for over 20 minutes with over 100 pings. All pings were registered on the south facing antenna.

The plot of signal strength (Figure 10) shows an initial period of high strength, followed by a period of no detections and finally a period of lower signal strength. It is likely that the bat continued moving during the period with no detections but it was screened from the receiver. There are a number of sea walls and dykes in proximity to the receiver so it's possible that the bat was travelling at low level behind one of these structures.

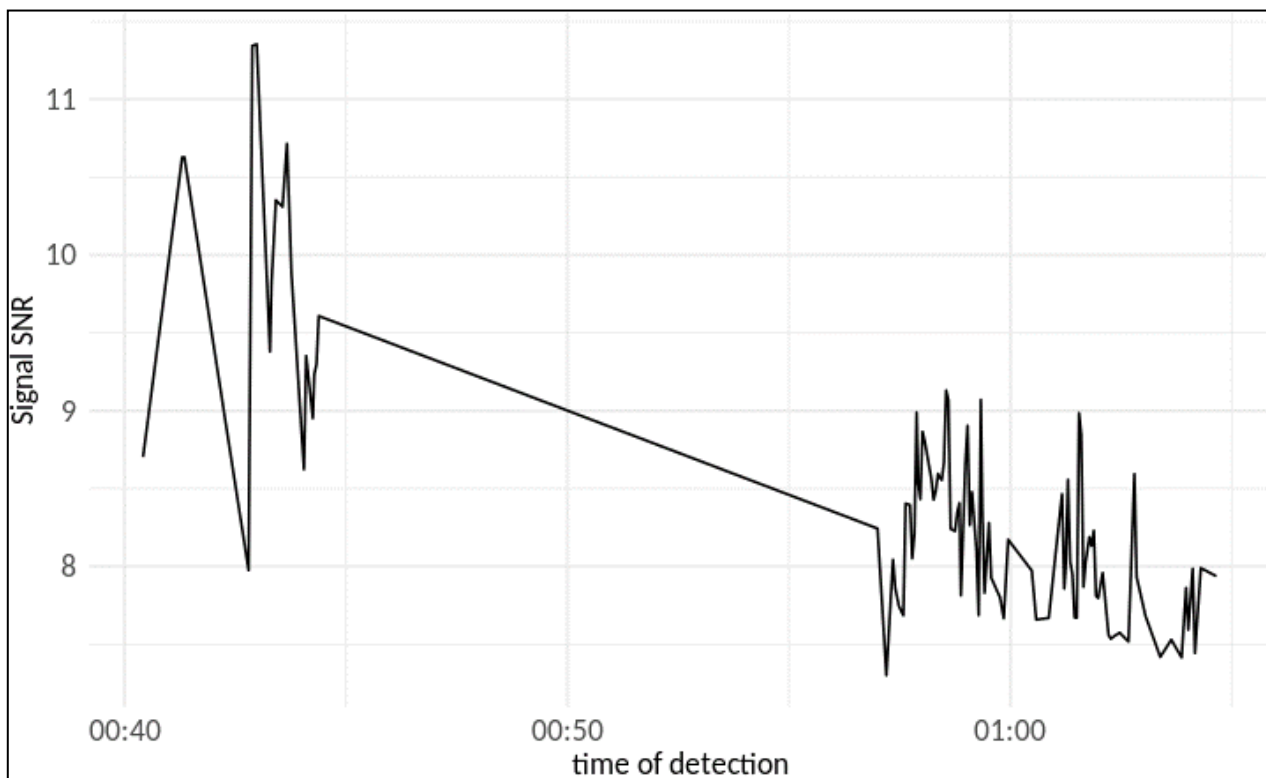


Figure 10: Tag 94 detected signal strength at Emssperrwerk receiver, Germany (Birds Canada, 2023c).

Flight Speed

The straight line distance from Landguard (UK) to Emssperrwerk (Germany) is approximately 430km. The bat covered this distance in 27 hours giving a minimum flight speed of 16km/h. As the bat likely roosted during day-light hours a more reasonable estimate of flight speed might be >30 km/hr. The bat crossed 170km of open water in less than three hours.

Tag 95 (♀) – East Anglia

This tag was only detected at Bedfont on the night it was tagged. Thereafter there were no detections for 17 nights (Table 6). On the evening of 4th May 2023 it was detected at Minsmere and then flew north up the East Anglian coast to Lowestoft as shown in Figure 11.

Table 6: Tag 95 First and last detections (Birds Canada, 2023c).

Receiver	First detection	Last detection
Bedfont Lakes	2023-04-16 22:28:01	2023-04-16 22:30:32
WUR Minsmere2	2023-05-04 20:20:42	2023-05-04 20:32:04
WUR Dunwich	2023-05-04 20:24:22	2023-05-04 20:42:16
Benacre NNR	2023-05-04 20:50:43	2023-05-04 20:57:38
WUR Benacre Pump Station	2023-05-04 20:57:06	2023-05-04 21:04:35
Lowestoft - CEFAS	2023-05-04 21:07:06	2023-05-04 21:10:44

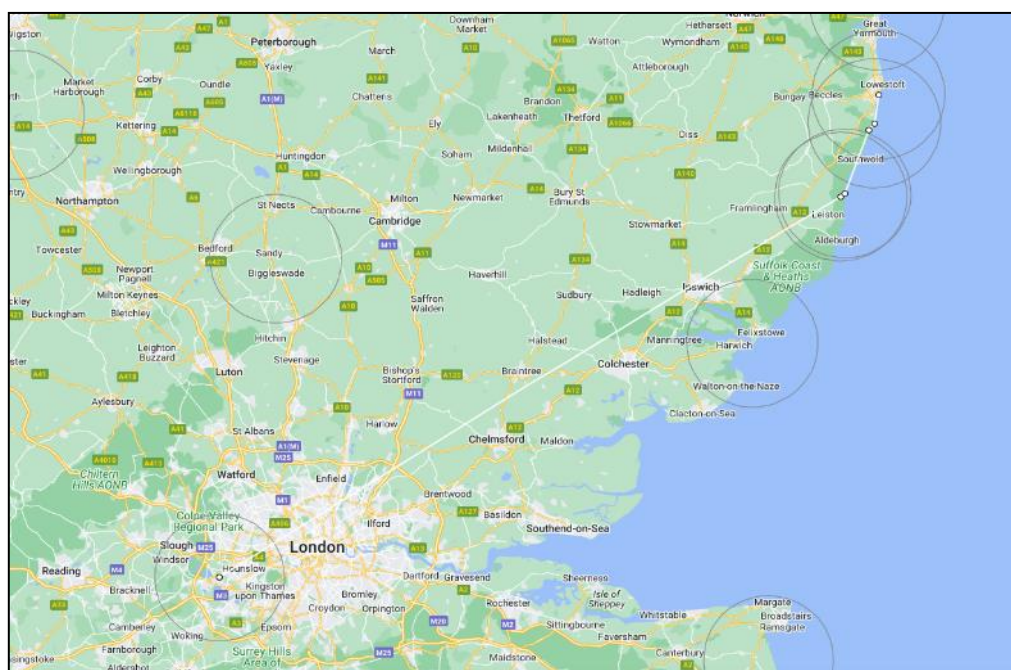


Figure 11: Tag 95 detections (Birds Canada, 2023b).

Minsmere/Dunwich

These receivers are located within 1km of each other giving detection coverage over the RSPB Minsmere Reserve and the Dunwich Heath NNR. The receivers are approximately 170km from Bedfont.

The tag was detected for a period of 22 minutes during which time over 1000 pings were recorded. From the signal strength information it is clear that the bat passed close to both of these receivers. It is likely that it arrived from the west/south-west and departed heading north.

Benacre NNR

The Benacre NNR receiver is located approximately 16km north of the receiver at Dunwich. This is also a coastal receiver albeit the receiver is located approximately 500m inland from the beach. The immediate area is a large expanse of open water and reed bed bordered by trees.

The tag was detected here approximately 11 minutes after the detections at Minsmere/Dunwich, giving a flight speed of over 80km/hr, albeit given the short distance between receivers and the uncertainty in when the bat was closest to the receiver this may be an over estimate. The tag was detected at this site for seven minutes during which time over 250 pings were recorded.

Benacre Pump Station

This receiver is located approximately 1km north east of the Benacre NNR receiver. The antennas are mounted on a building 20m from the high water mark. Due to local terrain there is no overlapping coverage with the Benacre NNR receivers for tags at low levels. The tag was detected at this receiver for seven minutes during which time over 75 pings were recorded.

Lowestoft

The Lowestoft receiver is located approximately 1.5km north of the Benacre Pump Station receiver. It is mounted on the roof of a building on the top of a cliff overlooking the beach below. The tag was detected at the receiver over a period of four minutes during which time 75 pings were recorded.

Flight Speed

The straight line distance between the Minsmere and Lowestoft receivers is 25km. We can estimate a range of flight speeds assuming a minimum and maximum flight time between those receivers as shown in Table 7.

Table 7: Estimated flight speeds of tag 95 (Birds Canada, 2023c).

Flight Speed Estimates			
Latest Lowestoft Detection	2023-05-04 21:10:44	Earliest Lowestoft Detection	2023-05-04 21:07:06
Earliest Minsmere Detection	2023-05-04 20:20:42	Latest Dunwich Detection	2023-05-04 20:42:16
Flight Time	00:50:02		00:24:50
Flight Time (hrs)	0.8		0.4
Distance (km)	25		25
Speed (km/h)	30		63

Beyond Lowestoft there are two further receivers at Caister (20km straight line distance) and Eccles (further 20km straight line distance). The tag was not detected on either receiver.

With a change in weather between 4th and 5th May (see wind direction and speed in Figure 12) it's possible that this bat attempted to cross the North Sea. With no detections from any of the continental receivers it's not known if it was successful.

Discussion

Of the bats tagged in a single session session 40% were found to have undertaken significant movement to the coast. Three may have attempted to cross the sea to mainland Europe but only one was detected on the European mainland, in the Netherlands and Germany (Figure 13).

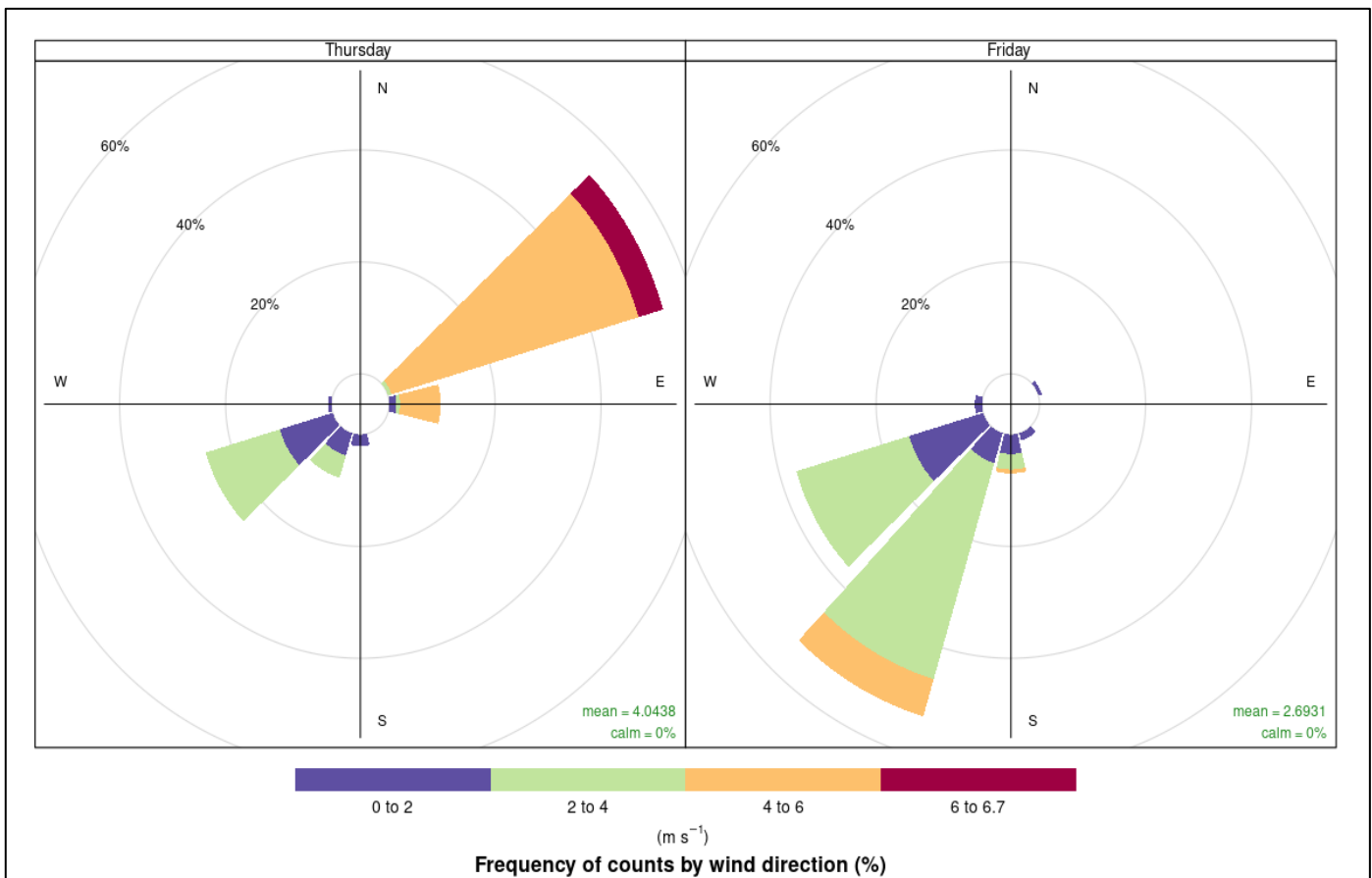


Figure 12: Windrose, Felixstow, counts of hourly readings on Thurs 4th May and Friday 5th May 2023 (Channel Coastal Observatory, 2023).

In spring 2023 there was a persistent north-easterly wind which probably delayed the migrating bats from leaving the UK coast. When the wind direction changed, tag 94 immediately crossed the channel. The batteries of tags 17, 92 and on the bats that went to the coast may have expired just before the wind direction changed. The presumption is that the bats on the coast could have crossed the channel at the same time but further research is needed. It could also be that the bats attempted to cross the channel and failed specifically tag 95 which was detected at four sites on the English coast on May 4th. Figure 12 shows the wind speed and direction on Thursday 4th May and Friday 5th May 2023.

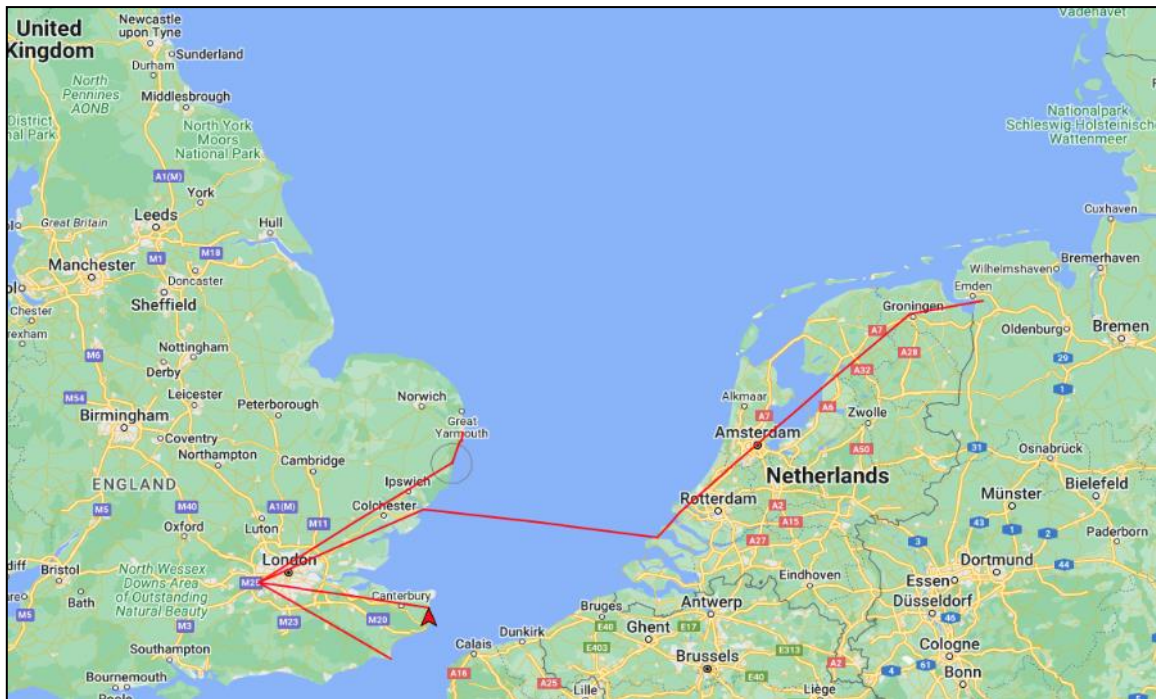


Figure 13: Dispersal routes of bats tagged on 16th April 2023 (Birds Canada, 2023b).

Without the need for recapture, and with longer battery life than conventional radio tags, the advantages of a wide deployment of Motus receiving stations in identifying migratory routes of *Nathusius' pipistrelle* bats are evident. It is generally possible to retrieve data very promptly as most of the receiving stations automatically download data daily to the Motus website. Others have to be manually downloaded and then uploaded to Motus, consequently some of the data will not be so promptly accessible.

One problem encountered with some of the tags was that the frequency of pulse transmission had been set too high, consequently those tags did not transmit for as long as others. A burst interval of seven or eight seconds seems to be the optimum setting for long distance migratory *Nathusius' pipistrelle*s. Up to 40 days of tracking can be achieved with this setting (Harris, 2023, pers. comm.). It is also important to ensure that the tags are carefully and securely fitted on bats that could be undertaking long migrations.

A Lotek SRX receiver with a hand held antenna can be used to manually track a tagged individual to a roost location. A Lotek Biotracker (adapted to cover 150MHz) can also be used but the advantage of the SRX receiver is that it displays the number of the individual tag it is decoding. The field technique using a Lotek SRX receiver is necessarily different to tracking with standard radio tags due to the slower pulse intervals.

Whilst ringing does not provide data as quickly accessible as Motus tagging, it is significantly less disturbing to the bat, requires fewer personnel, is much cheaper and does not rely on the installation of technological resources. The identification of an individual tagged bat is possible for a significantly longer period of time and there is an international and effective method of relaying capture data. Both identification methods should be viewed as complimentary.

There are now numerous Motus stations along the European coastline and some on the East Anglian coast. Installation of more sites in the UK would allow much more precise and comprehensive data. More UK inland stations will help plot migration routes.

With such interesting results from one tagging session at Bedfont Lakes, it is hoped to continue deploying tags during mid April to mid May in future years when females are most likely to be migrating to further increase our knowledge of migration routes. It is hoped that liaising with other bat groups around the UK will help establish additional Motus Tracking Stations which will add valuable information to the study of Nathusius' pipistrelles.

Acknowledgements

Thank you to the London Borough of Hounslow who own Bedfont Lakes Country Park and Lampton GreenSpace 360 Ltd who manage the site for the opportunity to survey the site. Thank you to the numerous volunteers, especially Matt Dodds, who have helped carry out the surveys since 2002. Thank you to Phil Cannings, Ewan and Sue Parsons who made and erected the Motus Tracking Station. Thank you to Jane Harris, Ewan and Sue Parsons for their continued help and advice; they have been using the Motus System for two years in East Anglia with good results. Thanks to the Dungeness Bird Observatory, Landguard Bird Observatory, Sandwich Bay Bird Observatory, Dr Sander Lagerveld (Wageningen Marine Research), Prof Barbara Helm (University of Groningen), Dr Vera Brust (Institute of Avian Research 'Vogelwarte Helgoland') and the Bat Conservation Trust.

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Bayfordbury eDNA trials: An experiment in democratising environmental DNA workflows for biodiversity monitoring and natural habitat conservation (interim report for University of Hertfordshire)

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Abstract

DNA metabarcoding research and commercial application has gathered pace over the last decade. While some studies have involved community scientists in the data collection stage, in this pilot study we explore the possibility of community scientists conducting complete DNA metabarcoding from data collection to final data analysis. A particular aspiration of the pilot was to lay the foundations for a transparent, repeatable workflow that could be picked up by groups of ‘non-molecular’ scientists, natural history experts and nature enthusiasts. Lab work was undertaken at the new Herts DNA Hub, the basic DNA lab kit was based on the portable ‘miniPCR16’ kit by MiniPCR and the final DNA sequence analyses were conducted using mBRAVE, an open access bioinformatics pipeline. Sequencing work was conducted by Deepseq at the University of Nottingham. This trial focussed on the identification of bat species and bat prey from the analysis of bat droppings. The pilot study was successful in that good quality DNA sequence data was obtained and bat prey taxa lists were produced that were consistent with the foraging behaviour of the bat species in question as previously described in the literature. To the authors’ knowledge this is the first demonstration anywhere in the world of a community science DNA metabarcoding workflow exploring ecosystem interactions. As with all DNA metabarcoding studies a key limitation is the lack of reliable information on taxa abundance and a key challenge is the potential for ‘false negatives’ due to primer bias and gaps in DNA barcode reference libraries.

Introduction

In January 2023 the Herts DNA Hub was set up at the Bayfordbury Life Science Campus with funding from the Darwin Tree of Life Enabling Communities Fund. The purpose of the hub is to explore if and how local community scientists and natural history enthusiasts and experts could learn to use DNA barcoding to generate new insights into local biodiversity. As part of this, and drawing on ecological expertise at Bayfordbury it was decided to trial the application of DNA metabarcoding to explore the diet of different bat species from DNA analysis of their droppings. Methods have been developed but very few studies from outside academia have been attempted let alone published. If a DNA hub like Bayfordbury, led by local naturalists with no prior background in molecular biology, could become ‘fast followers’ in the application of such techniques then it could become a model for replication across the UK to accelerate the validation adoption and application of DNA metabarcoding protocols from the research community.

Materials and Methods

Bat droppings sample collection

Five sets of bat droppings were collected by members of the Herts and Middlesex Bat Group (HMBG); two fresh bat dropping samples from 2FN Schwegler bat boxes at Bayfordbury (Figure 1) in May 2023 collected under licence (from separate boxes with brown long-eared bat *Plecotus auritus* and Leisler's bat *Nyctalus leisleri* present), one from a bat box at below the entrance to a Natterer's bat *Myotis nattereri* maternity roost at Ashwell Church Hertfordshire in June 2022 under licence, and two grounded bats (common pipistrelle *Pipistrellus pipistrellus* and soprano pipistrelle *P. pygmaeus*) brought into care through the UK Bat Care Network that were soon to be released back into the wild at Bayfordbury. The bat droppings covered a wide range of freshness/quality from less than 48 hours in the case of the samples from the rescued bats, to one year in the case of the Ashwell Church samples. The rescued bats had been fed only commercially bred mini mealworms *Tenebrio molitor* serving as a useful positive control.



Figure 1: Bayfordbury woodland habitat and bat droppings samples collected from bat boxes.

DNA barcoding workflow overview

A full description of the workflow is beyond the scope of this article but is available from the author on request. The lab work was conducted using equipment supplied by MiniPCR and following a protocol developed after consultation with ADAS and mBRAVE (Figure 2). The full workflow is available on request and can be learnt in approximately one week. The polymerase chain reaction (PCR) lab workflow involves carefully following a 22 step protocol – not unlike following an elaborate recipe for baking a cake. The bioinformatics step requires an email account and an ability to upload and download a few 10MB files.

The essence of DNA barcoding is to analyse short fragments of DNA that are ‘species diagnostic’. High concentrations of these DNA fragments are obtained using PCR (as used in COVID-19 testing) a technique which uses chemical ‘primers’ to strip out and then replicate (or ‘amplify’) the target DNA fragments. For simplicity, in this study we used general ‘CO1’

primers designed for the analysis of all metazoan DNA (vertebrates and invertebrates) in a single workflow.

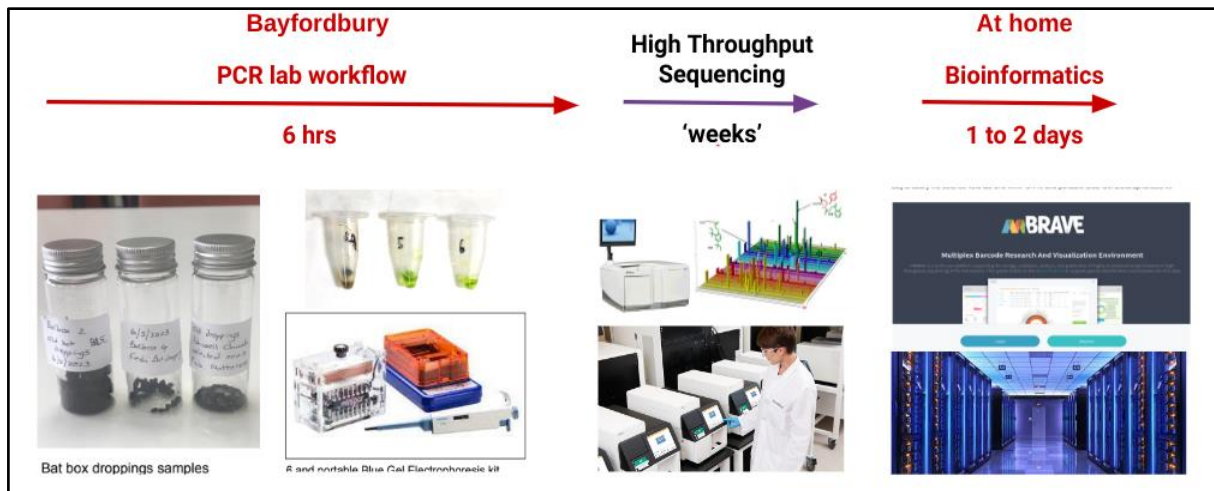


Figure 2: DNA metabarcoding barcoding three-stage workflow.

Stage 1: PCR lab workflow

The initial PCR lab workflow was performed at the Bayfordbury Life Science Lab (Figure 3) which is an ecology field lab as opposed to a lab purpose built for genomics research. This step involved the use of spin columns to lyse, wash and elute the DNA in the samples, and the first stage PCR step involved use of a MiniPCR16 and portable Blue Gel Electrophoresis kit. After extracting the DNA from samples, the PCR step amplifies a short, species-diagnostic section of DNA billions of times so that the DNA barcodes (or genetic fingerprints) can be sequenced for subsequent bioinformatics analysis.

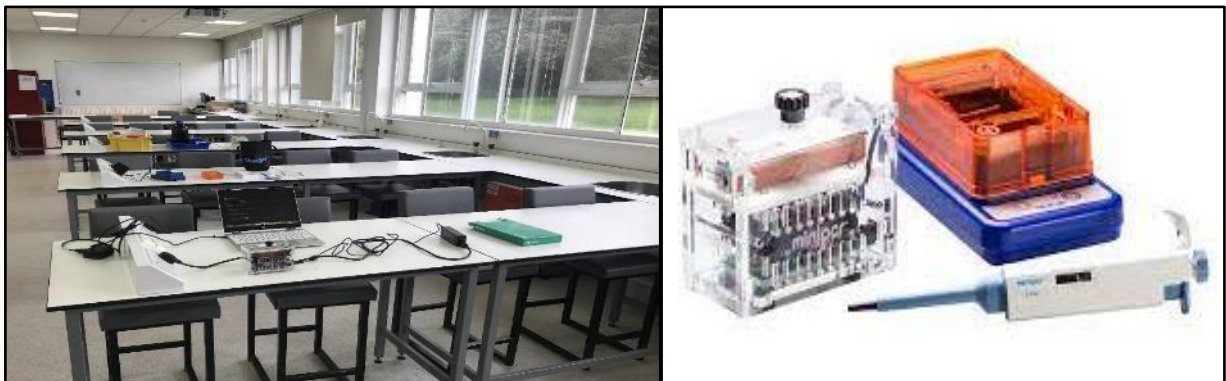


Figure 3: Bayfordbury lab and portable MiniPCR equipment.

Stage 2: High throughput sequencing

The high throughput sequencing step involves establishing the DNA sequences for all the DNA fragments present in samples. For this trial it was decided to do this step off-site using a service provided by Deepseq at Nottingham University but plans are already in place to look at low cost portable kits to enable this step to be conducted at Bayfordbury potentially enabling the full workflow to be conducted within one day.

Stage 3: Bioinformatics

The DNA sequence data files from Deepseq were received by email. The DNA codes were then analysed using the open access mBRAVE platform. Bioinformatics runs were set up on a simple Chromebook computer and submitted online for computational analysis at high performance computing facilities at the University of Guelph in Canada. After some preparatory steps (filtering and dereplication) mBRAVE matched the DNA sequences to the following global reference databases, which contain more than 200,000 taxa, in the Barcode of Life Database (BOLD):

- Human contamination
- Lab/PCR contamination (17 common contaminants)
- Bacteria
- Protista
- Fungi
- Chordata
- Aves
- Insects
- Non Insect Arthropods
- Non Arthropod Invertebrates

Results were received within hours of submitting runs and three runs were required for optimisation.

Results

Only bat DNA and invertebrate DNA was matched and there was no evidence of any contamination with one exception, which was the presence of fungal DNA on the oldest dropping sample.

With one exception discussed later, all 80 taxonomic identifications from DNA metabarcoding were of taxa previously recorded in Hertfordshire or neighbouring counties according to the National Biodiversity Network (NBN) Atlas.

Bat species Identification

Two of the three wild bats were correctly identified to species level (brown long-eared bat from Bayfordbury and Natterer's bat from Ashwell) and one of the two rescued bats was correctly identified but only to genus level *Pipistrellus*. The remaining two bats could not be identified directly from DNA due to 'primer bias' as is discussed later. However, the species of the third wild bat, a Leisler's bat, was correctly identified through interpretation of its prey as part of a 'blind test'.

Invertebrate identification

The diet of two rescue bats was correctly identified as mealworm. For the three wild bats the prey were diverse. Full taxa lists are provided in Appendix A and are summarised in Table 1 and Figure 4. In many cases (n=30) prey taxa identification was possible to species level whilst in other cases taxa could only be identified to closely related species group level (n=20) or genus level (n=27).

Table 1: Invertebrate identification summary table.

Order	Species level identifications	Species group identifications	Genus level identifications	Total taxonomic diversity
Diptera	5	20	20	45
Coleoptera	7	0	1	8
Hymenoptera	2	0	2	4
Hemiptera	0	0	2	2
Lepidoptera	5	0	0	5
Neuroptera	1	0	0	1
Trichoptera	1	0	1	2
Araneae	3	0	1	4
Orthoptera	2	0	0	2
Enteromorpha	1	0	0	1
Opisthopora	1	0	0	1
Isopoda	1	0	0	1
Siphonaptera	1	0	0	1
Total inverts	30	20	27	-

Genus level identifications are particularly high in orders such as Diptera where morphological identification even to family level involves very rare taxonomic skill. For these taxa, many of the DNA sequences in reference databases do not yet contain species level labels.

The invertebrate taxa lists have been shared with the appropriate Hertfordshire biological recorders. Work is ongoing to interpret these lists and integrate them with existing knowledge from county monitoring.

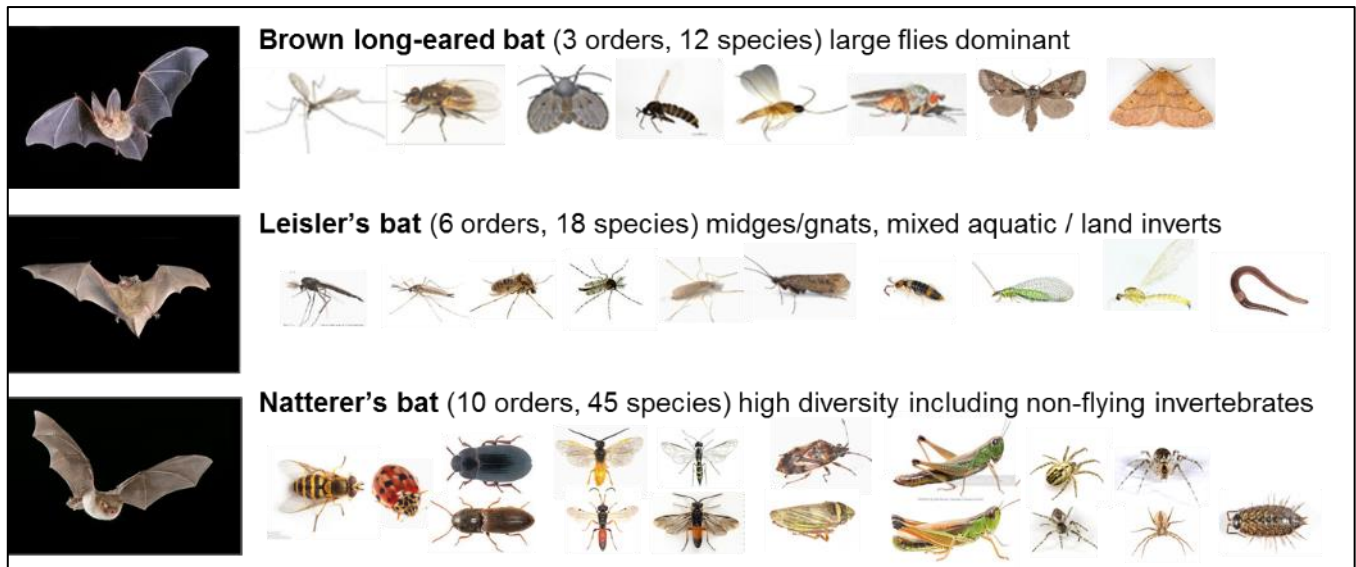


Figure 4: Summary of the three wild bat species and their prey (full taxa lists in Appendix A).

Bat diet interpretation

Previous DNA metabarcoding work on bat droppings (e.g. Ware, 2016) in the UK has revealed a dominance of Lepidopteran and Dipteran prey (see the chart in Appendix B, taken from Ware, 2016) although there it has been demonstrated that there is more order-level diet diversity for some bat species than others.

Overall, the bat diet results from this study are very much in alignment with field observations of bat species specialism and foraging behaviour as shown in Figure 5 (foraging diagrams from University of Bristol, 2005)

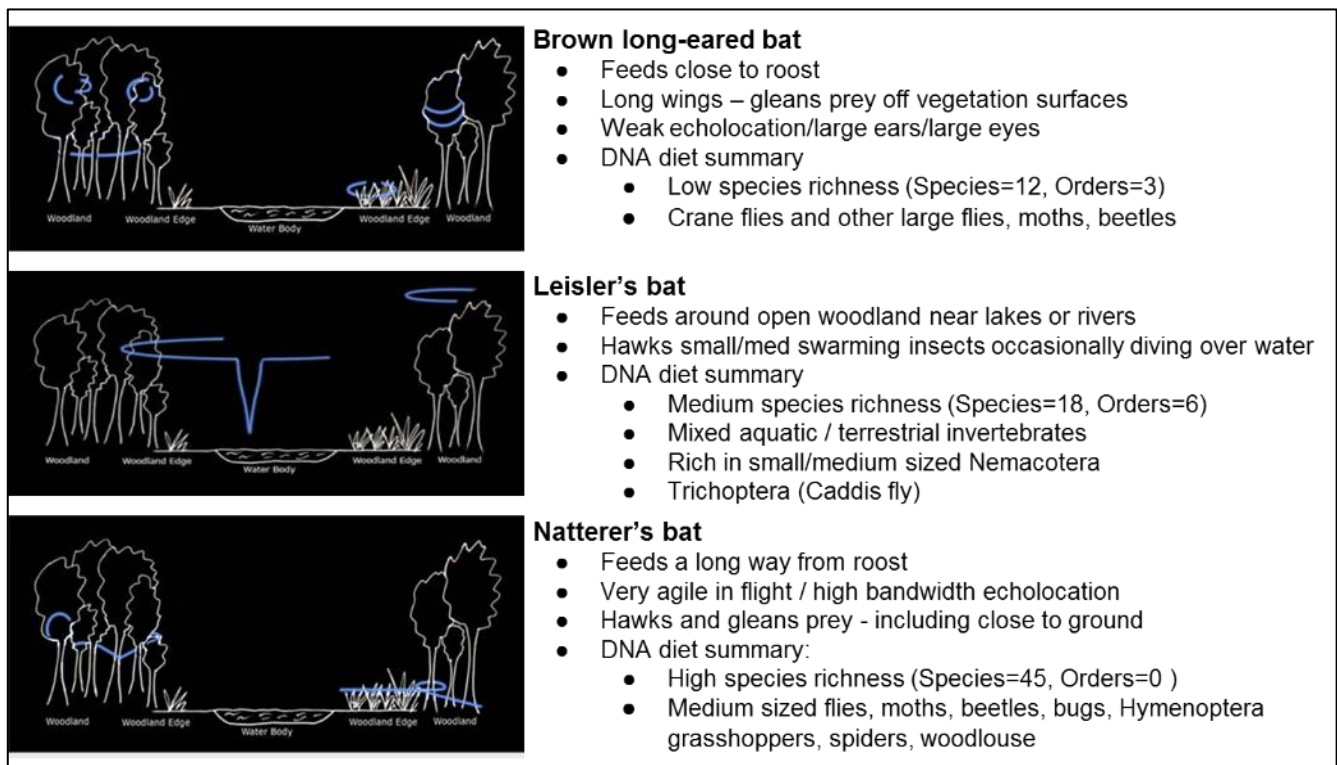


Figure 5: Bat species foraging behaviour and diet summary from this study.

The brown long-eared bat sample results suggests a diet of crane flies, other medium to large sized Diptera, Lepidoptera and Coleoptera. This is entirely consistent with the brown long-eared bat being a slow flying species that relies on strong visual and passive audio clues without relying on echolocation. These bats feed in deciduous woodland within c. 0.5km of roost sites and typically forage by 'gleaning' insects off vegetation and other surfaces.

The diet of the second bat (itself unidentified by DNA but known to be a Leisler's bat) is rich in small aquatic Diptera. Three UK bats are known to forage at least occasionally over water: Daubenton's bat *M. daubentonii* (the 'water bat'), noctule *N. noctula* and Leisler's bat. The observed diet is most consistent with the foraging behaviour of Leisler's bat. Leisler's bats are not regularly observed at Bayfordbury and have not until 2023 been found in the bat boxes there, which are checked regularly and have been in place since 2016. Leisler's bats are known to forage over lakes, mixed woodland and open areas. Their diet is believed to vary according to habitat but they often prey on medium sized Nematocera, Diptera and Trichoptera which is a close and quite distinctive match to the results of this study. Nematocera is the suborder of flies that includes all thin-bodied flies (as opposed to fat-bodied flies which were more common in the diet of brown long-eared bats). Also a Leisler's bat diet would be expected to include some terrestrial invertebrates which is again consistent with the results of this study.

The Natterer's bat sample from Ashwell Church showed the most diverse diet (40 species/ species groups) consisting largely of medium sized Diptera and Coleoptera but also included Orthoptera, Hemiptera, Neuroptera, Lepidoptera and four species of Arachnida. This high level of diversity is consistent with a bat that has a long foraging range, is able to catch prey by both hawking in open flight and gleaning off surfaces and which can forage over a variety of natural habitats (woodland, grassland, open water), and matches what has been found by other studies (Ware, 2016). It has been hypothesised in the literature that a high diet diversity is correlated to adaptability to environmental stressors but this is yet to be proven.

In summary the results suggest a high degree of congruence between the bat diets observed and previous research on interspecific specialisms and foraging behaviour for the individual bat species in this study. The small study also highlighted the high level of taxonomic diversity of bat diets with up to 40 distinct taxa groups, perhaps more, being consumed in a single night.

This small study was not able to shed any light on bat diet variability as a function of season. One surprise perhaps of the study was the relative paucity of Lepidoptera prey for the brown long-eared bat. One possible explanation is that these samples were collected in spring when night time temperatures were still cool and Lepidoptera abundance may have been low. Based on nocturnal moth phenological studies an expectation would be that summer/autumn bat droppings would be richest in Lepidoptera.

Study Learnings – what went well?

A world first demonstration of a community science DNA barcoding workflow

To the best of the authors' knowledge this is the first successful demonstration anywhere in the world of a community science DNA barcoding workflow being applied to gain insights into the diet of different species of bat and the workflow can be applied to other types of

ecosystem interaction. It is conceivable that other DNA hubs could be established across the UK to expand the application of DNA metabarcoding analysis to study biodiversity and ecosystem interactions. This could be achieved with small funding and an inter-community ‘train the trainer’ program.

Apparent robustness to age of samples

The Natterer’s bat sample from Ashwell Church was over a year old. This sample resulted in a correct bat species identification and the highest invertebrate taxonomic diversity of all the samples. This is an important finding as quite often wild bat droppings are not collected fresh.

Successful interpretation of a bat species from its DNA-derived prey list

As mentioned earlier, in a ‘blind test’ the Leisler’s bat was correctly identified through an interpretation of its diet. Whilst this was an interesting piece of ‘ecosystem interaction detective work’ it is always better to identify bat species directly from the bat DNA in droppings rather than indirectly via dietary interpretation.

New invertebrate species for Bayfordbury and Ashwell

Bayfordbury has been a site of ecological and conservation interest since 1767 when the first conifers were planted by the Baker family (subsequently becoming the Clinton-Baker Pinetum). Over recent decades the site has been continuously studied by environmental science and ecology students at the University of Hertfordshire. Ashwell, in contrast, has never been monitored for invertebrates. The results of this study supports the presence of many invertebrate taxa that have never been previously recorded at these locations.

It is not recommended that invertebrate taxa/species lists derived from DNA metabarcoding of bat droppings are entered into public databases such as iNaturalist. One reason for this is that the exact location can never be known. However, it is good practice to notify the relevant County Biological Recorders of anything unusual. It may be deemed a false identification (see section below) or it may be deemed an important new finding.

An expanded role for Community Science in UK ecosystem monitoring

The success of these trials in terms of low-cost and rapid learning suggests that community scientists can play an active role in advancing DNA metabarcoding beyond data collection. Small scale, agile projects with rapid learning cycles like these Bayfordbury trials (Figure 6, Tier 2) can complement the deeper but slower learning cycles (Figure 6, Tier 1) from larger research and monitoring schemes.

This model with fast Tier 2 learning cycles (Figure 6) is being put into practice in a new project which will focus on testing a new, improved CO1 primer for aquatic eDNA analysis (trace DNA in water samples). The results of this short study could impact the 2024/5 GenePools project (Tier 1) coordinated by the Natural History Museum involving Community Scientists from six cities across the UK. In addition small studies will be designed to support the UK BIOSCAN project, a multi-year programme to identify malaise trap specimens and their ecosystem interactions from 100 sites across the UK.

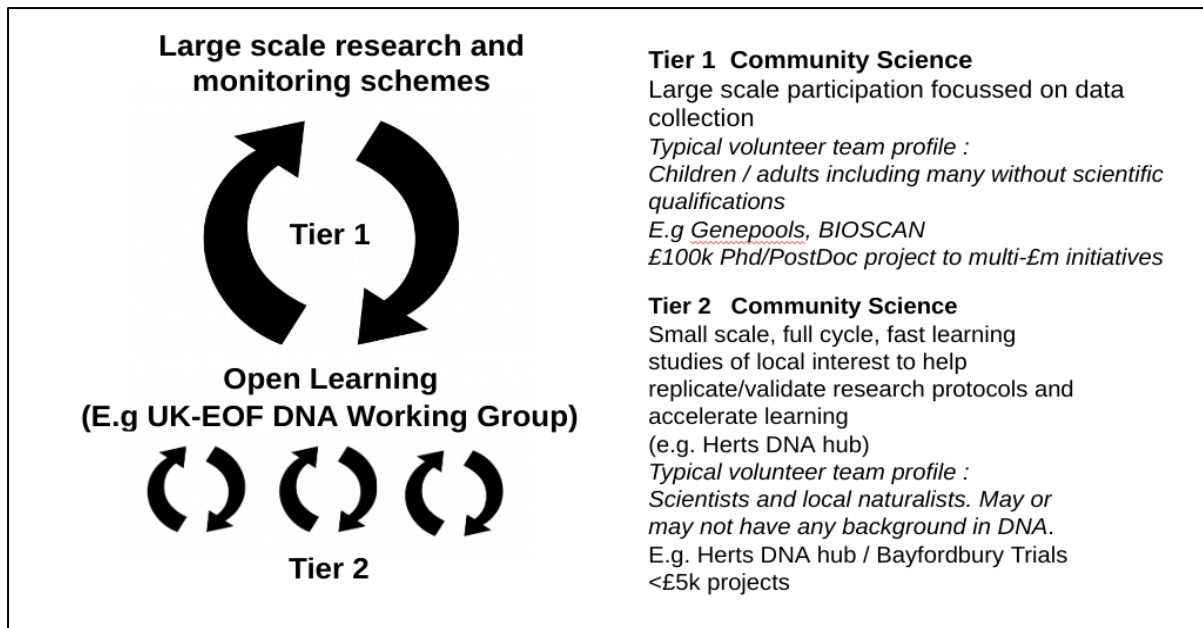


Figure 6: Collaborative model for DNA-based learning involving community scientists.

Study Learnings – limitations and areas for improvement

Lack of abundance information

One of main limitations in DNA metabarcoding is the inability to gather reliable information on abundance. This is partly due to primer bias and partly due to differences in biomass (a large worm will have as much DNA as a swarm of midges). Research is ongoing to try to enable estimations of abundance but in the foreseeable future it seems likely the DNA barcoding results and interpretation will be restricted to taxonomic diversity.

Missing species (false negatives)

Perhaps the most likely cause of false negatives is ‘primer bias’ and it is a well known and largely unavoidable problem. Primer bias occurs where the target sections of DNA of certain taxa are preferentially amplified in the PCR process at the expense of others. It is likely the reason why two of the five bats could not be identified directly through DNA is because the invertebrate DNA in the samples was preferentially amplified in the PCR process. A simple way around this is to conduct a second PCR which specifically targets bat DNA. It is an extra step albeit easy to do. In this study the rescue bat species was well known and the Leisler’s bat species had been confidently identified in hand by licenced members of HMBG, hence it was not necessary to undertake further analysis.

As for the invertebrates, whilst this study has generated extensive and diverse taxa lists it is very likely that these lists are incomplete because of primer bias. The level of false negatives is unknown but in DNA metabarcoding trials of mock invertebrate bulk samples (where the taxa content of samples are known) it is typical for 10-30% of taxa to be missed. Moreover, some orders of invertebrates will likely be missed more than others.

Optimisation of primers is a continuous area of research and the Herts DNA hub is currently assisting in validating new primers designed by experts at the Natural History Museum.

False identifications (false positives)

It is quite unlikely for one section of DNA to be falsely matched to an equivalent section of reference DNA in a global database. It would be akin to someone guessing the code for a bicycle combination lock with 200 rotating wheels. However, if the reference DNA is incorrectly labelled the species identification will be incorrect. A likely example of this is the Marsh Meadow Grasshopper *Pseudo curtippennis* identified in this study in the Natterer's bat sample. The Meadow Grasshopper *Chorthippus parallelus*, also identified in the sample, is native to the UK, but the Marsh Meadow Grasshopper is native to the US and has never been recorded in the UK. It therefore seems very likely that this is a false identification due to some sort of database labelling error.

Invertebrate prey and coprophagous invertebrates

Some invertebrates are predatory and so it is possible that some of the identified invertebrate DNA is from the prey of invertebrates preyed on by bats. An example of this might be the earthworm identified in the Leisler's bat dropping. To the authors' knowledge UK bats are not known to feed on earthworms but Coleoptera, for example, may do. The earthworm is therefore either a false bat prey identification or an interesting new finding. This is unlikely to be a major issue as the amount of DNA from any invertebrate prey is likely to be very small and it would be twice digested. In addition some invertebrates are coprophagous (feed in faeces) and may not be bat prey. Possible examples are latrine flies *Fannia sp.* and moth flies *Psychoda sp.*, which were identified in the brown long-eared bat droppings.

Follow up ideas being considered

In March 2023 Bayfordbury was accepted as a BIOSCAN partner site involving the collection and analysis of flying insect samples collected throughout the year. This study has demonstrated that local bats consume a higher diversity of invertebrates than are trapped in malaise traps. Malaise traps are static whereas bat foraging is highly dynamic and covers a wide range of habitats. To put this into context, the single Natterer's bat sample with 40 different invertebrate taxa captured as much order level diversity as six months of Bayfordbury malaise traps (1,500 samples). The Bayfordbury bats could even be used throughout the year as community scientists (Figure 6, Tier 1) to collect samples to augment the BIOSCAN studies.

Further down the line the use of a portable nanopore sequencer could be used to allow the high throughput sequencing step to be done 'in-house'. This would mean that samples could be collected and analysed in one or two days. In addition nanopore Sequencers would enable longer read analysis for more complex genomics studies.

The Herts DNA hub is well set to build on new breakthroughs in DNA science. For the immediate future the focus will be making full use of the DNA barcoding and metabarcoding capabilities developed this year.

Acknowledgements

Thanks to Sam Rowe from the Earlham Institute and Luke Lythgoe from the Wellcome Sanger Institute for helping get initial funding for the Herts DNA hub. Thanks to the architects and sponsors of mBRAVE and BOLD – two open access initiatives which have been

instrumental to the success of this project. And finally thanks to all the global experts who have provided guidance and encouragement throughout 2023.

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Appendix A – bat droppings full taxa list

Table 1: Scientific name, image and common name by bat species sampled.

Scientific name	Image	Common name
Bat: <i>Plecotus auritus</i>		Brown long-eared bat
<u>Order Diptera:</u>		
<i>Tipula sp.</i>		Crane flies
<i>Tephrochlamys sp.</i>		None
<i>Fannia sp.</i>		None
<i>Psychoda sp.</i>		Filter flies
<i>Chironomus sp.</i>		Non-biting midges

Scientific name	Image	Common name
<i>Scatpose notata</i>		Scavenger fly
<i>Lycoriella agraria</i>		Black fungus gnat
<u>Order Coleoptera:</u>		Rove beetles
<i>Atheta sp.</i>		
<i>Tenebrio molitor</i>		Darkling beetle species
<u>Order Lepidoptera:</u>		Green-brindled crescent moth
<i>Allpophyes oxyacanthae</i>		
<i>Endrosis sarcitrella</i>		White-shouldered house moth
<i>Colotois pennaria</i>		Feathered thorn moth
		

Scientific name	Image	Common name
Bat: <i>Nyctalus leisleri</i> <u>Order Diptera:</u> <i>Chironomus sp.</i> <i>Glyptotendipes sp.</i> <i>Polypedilum sp.</i> <i>Procladius sp.</i> <i>Chaoborus sp.</i> <i>Orthocladius sp.</i> <i>Prodiamesa sp.</i> <i>Mirotendipes sp.</i> <i>Zapremia sp.</i> <i>Megaselia lucifrons</i> <i>Copromyza sp.</i>	       	Leisler's bat Midges Midges Midges Midges Midges Midges Scuttle fly Lesser dung flies

Scientific name	Image	Common name
<i>Phaonia valida</i>		Muscid fly species
<i>Molophilus sp.</i>		Crane flies
<i>Rhipidia maculata</i>		Crane fly
<i>Tipula sp.</i>		Crane flies
<u>Order Coleoptera:</u>		
<i>Dromius quadrimaculatus</i>		Ground beetle species
<u>Order Trichoptera:</u>		
<i>Limnephilus affinis</i>		Caddisfly species
<u>Order Neuroptera:</u>		
<i>Chrysopa sp.</i>		Lace wings
<u>Order Lepidoptera:</u>		
<i>Sunira circellaris</i>		The Brick moth

Scientific name	Image	Common name
<u>Order Enterobryomorpha:</u> <i>Entomobrya albocincta</i>		Springtail species
<u>Order Crassiditella:</u> <i>Dendrobaena venata</i>		Earthworm species
Bat: <i>Myotis nattereri</i> <u>Order Diptera:</u> <i>Opesia atrata</i> <i>Syrphus sp.</i> <i>Calliphora sp.</i> <i>Empis sp.</i> 20 other Diptera species groups	   	Natterer's bat none Hoverfly Blow fly species None 20 other diptera species groups

Scientific name	Image	Common name
<u>Order Coleoptera:</u>		
<i>Harmonia quadripunctata</i>		Cream-streaked ladybird
<i>Agriotes sputator</i>		Click beetle species
<i>Agriotes lineatus</i>		Click beetles species
<i>Attagenus pello</i>		Fur or carpet beetle
<i>Alphitobius diaperinus</i>		Darkling beetle species
<u>Order Orthoptera:</u>		
<i>Chorthippus parallelus</i>		Meadow grasshopper
<i>Pseudo curtippennis</i> (USA native)		Marsh meadow grasshopper
<u>Order Hymenoptera:</u>		
<i>Cephus pygmeus</i>		Wheat stem borer

Scientific name	Image	Common name
<i>Dolerus sp.</i>		Sawfly species
<i>Eura fallax</i>		Sawfly species
<i>Tycherus sp.</i>		Parasitoid wasp species
<u>Order Lepidoptera</u>		
<i>Endrosis sarcitrella</i>		White shouldered house moth
<u>Order Hemiptera</u>		
<i>Kleidocerys sp.</i>		Seed bug species
<i>Aphrodes sp.</i>		Leafhopper species
<u>Order Neuroptera:</u>		
<i>Hemereobius stigma</i>		Brown pine lacewing
<u>Order Siphonaptera:</u>		
<i>Ischnopsyllus variabilis</i>		Flea species

Scientific name	Image	Common name
<u>Order Araneae:</u>		
<i>Mangora acalypha</i>		Cricket-bar orb web spider
<i>Cyclosa conica</i>		None
<i>Philodromus collinus</i>		None
<i>Platnickina sp.</i>		None
<u>Order Isopoda:</u>		
<i>Philoscia muscorum</i>		Woodlouse
Bat: <i>Pipistrellus sp.</i>		Pipistrelle species
<i>Tenebrio molitor</i>		Mealworm
Bat: species not identified		
<i>Tenebrio molitor</i>		Mealworm

Appendix B - Summary of bat diets

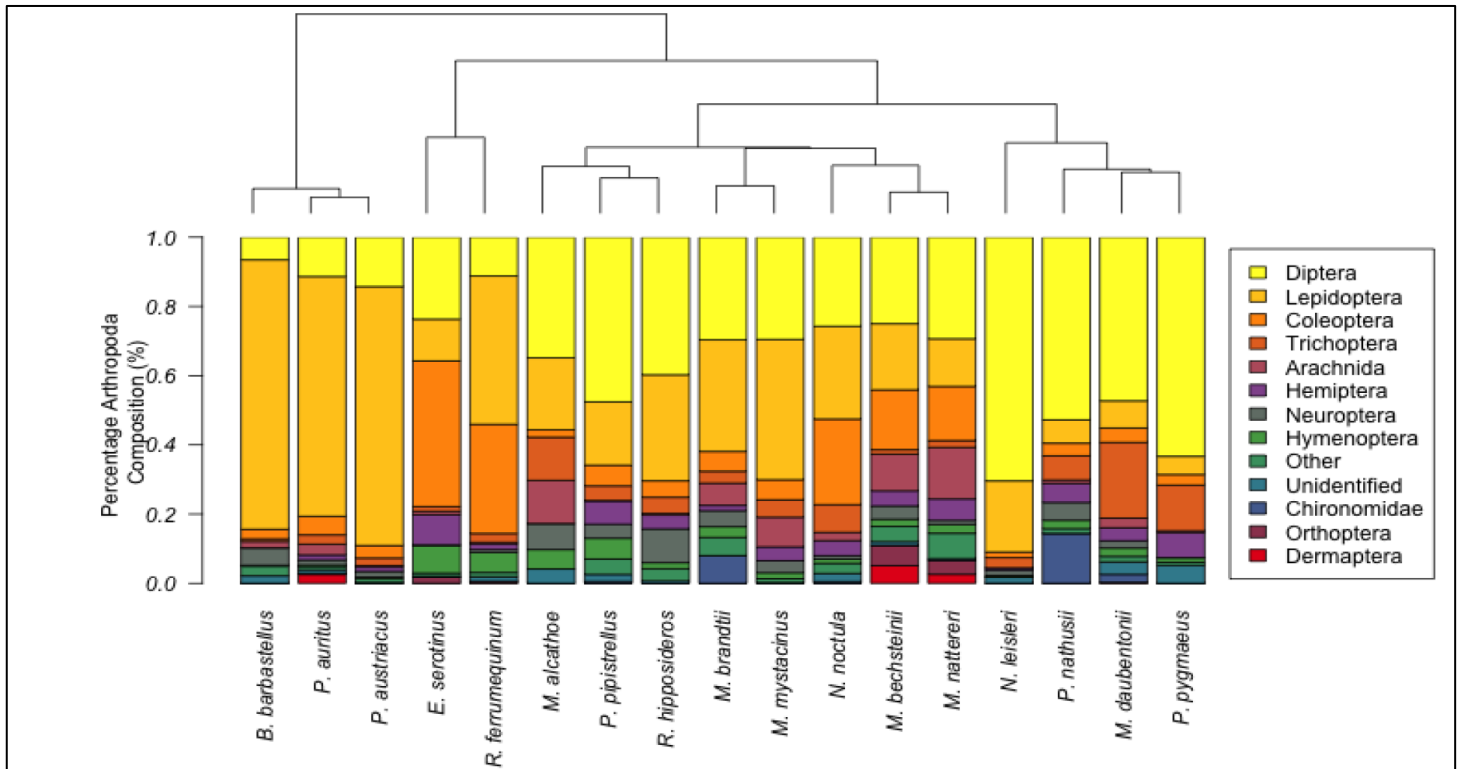


Figure 1: The diet of each bat species from the literature, taken from Ware, 2016 (page 35, Figure 2.2)

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Now you hear them, now you don't: An acoustic survey of bat activity around South Wonston, Hampshire, in 2022

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Introduction

First appearing in the fossil record around 50 million years ago (Brown *et al.*, 2019), bats have since evolved to become one of the most diverse and geographically dispersed kind of living mammals on the planet (Hutson, 2022). They are unique in that they are the only living mammals capable of sustained powered flight and sophisticated echolocation. As a bioindicator species (Russo and Jones, 2015; Russo *et al.*, 2021), bats can reveal the health of their habitat and the species they rely on. Using low-cost, non-intrusive, bat detectors, citizen scientists can support studies of their relative abundance and activity (Barlow *et al.*, 2015), which can contribute to the identification of the drivers of their population change (Browning *et al.*, 2021). To better understand my local bat population, this article presents the results of an acoustic survey of bat activity around the Hampshire village of South Wonston in 2022, and complements earlier ad hoc observations of bat activity that I have reported to the iNaturalist citizen science platform with a more systematic study.

Site location and previous bat observations

The village of South Wonston is located approximately 5km due north of the city of Winchester on a ridge of chalk downland at an elevation of around 100m above mean sea level. First established in 1892, the village has grown to around 1,500 dwellings, mostly dating from the 1960s and 1980s, and a population of approximately 2,870 in 2017. Covering an approximately rectangular area of 60ha orientated east/west along the ridge line (Figure 1), the village is bordered by open downland that is broken up into arable and grazing fields with trees, hedgerows and small woodland areas. Except for ponds in gardens, there is no open water in the village and other than the main thoroughfare through the village, there is no street lighting along most of the roads. Further information on the character of the village and its environs can be found in the Village Design Statement (SWPC, 2014).

Between 2018 and 2019, occasional recordings of bat activity around the village were made using a Wildlife Acoustics EM3+ bat detector and uploaded to the iNaturalist citizen science platform (iNaturalist, 2022). Sixty research grade observations were made covering six species:

- common pipistrelle *Pipistrellus pipistrellus* (44 observations, 73.3%)
- soprano pipistrelle *P. pygmaeus* (three observations, 5.0%)
- Nathusius' pipistrelle *P. nathusii* (one observation, 1.7%)
- noctule *Nyctalus noctula* (nine observations, 15.0%)
- serotine *Eptesicus serotinus* (two observations, 3.3%)
- brown long-eared bat *Plecotus auritus* (one observation, 1.7%)

Figure 2 shows the distribution of these observations around the village (note that the single Nathusius' pipistrelle observation is hidden amongst the cluster of observations in the south-west corner of the map (location OR)).

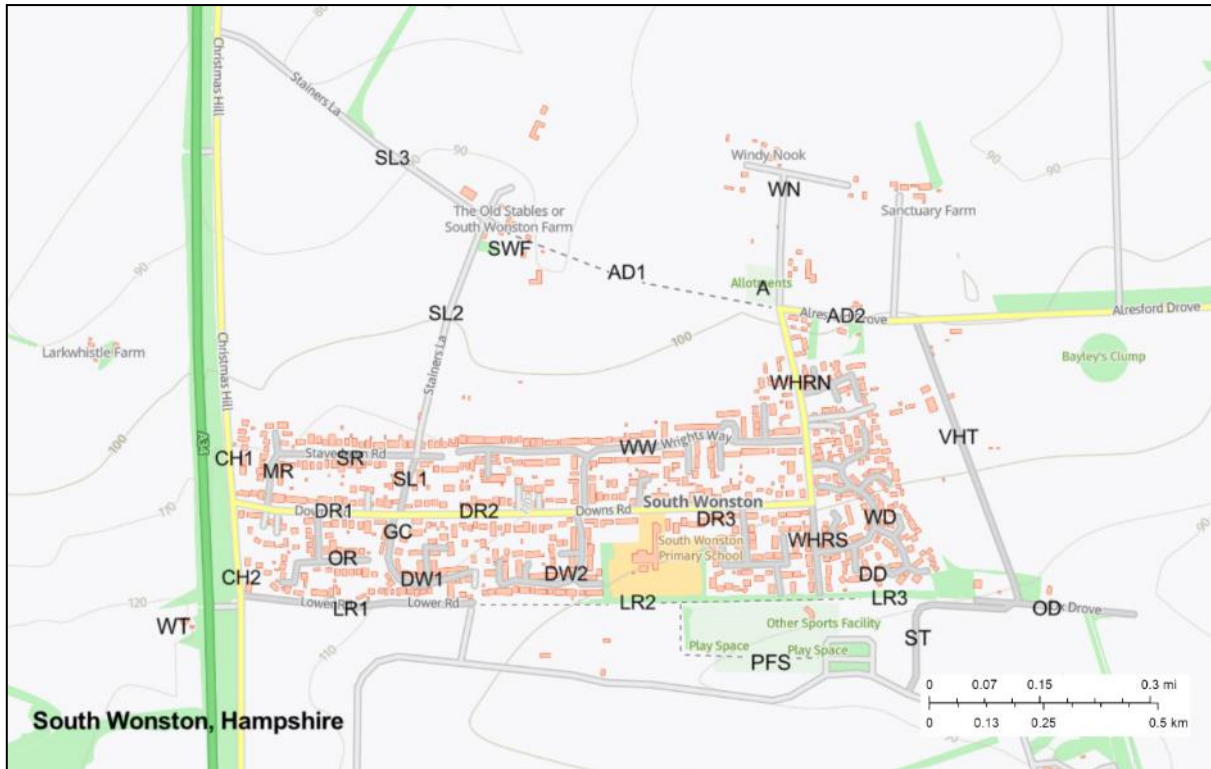


Figure 1: Map of South Wonston, Hampshire, showing the locations covered by the 2022 survey transects (see Table 1 for details). ESRI GB Cartographic basemap contains OS data © Crown Copyright and database rights 2022.

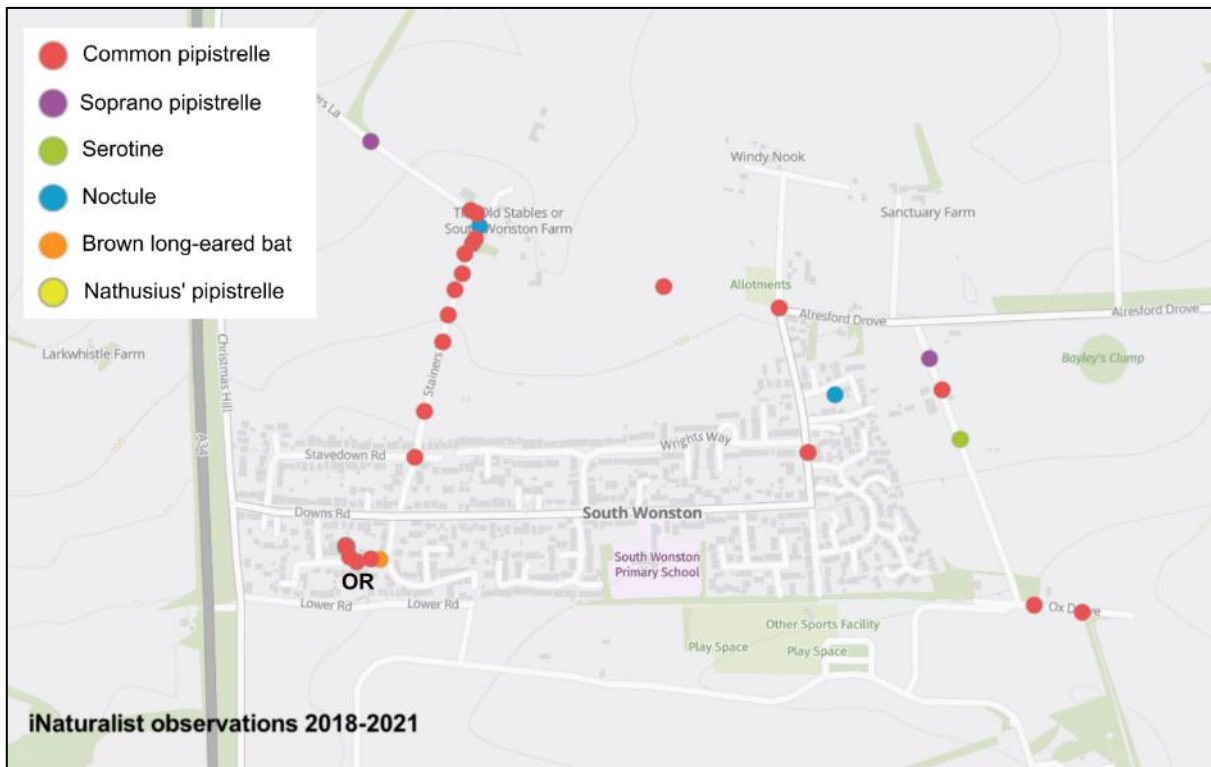


Figure 2: Distribution of observations of bat echolocation call recordings reported to iNaturalist between 2018 and 2021. ESRI GB Background basemap contains OS data © Crown Copyright and database rights 2022.

Method

Transects and data recording

Between 25th May and 19th August 2022, I walked a series of 19 transects along roads and public footpaths around the village starting from around sunset (Table 1). Ground tracks of transects were recorded with a Samsung M52 smartphone using the Strava app, which also provided real-time location tracking as a safety feature. Geo-referenced bat calls were recorded using a Wildlife Acoustics Echo Meter Touch 2 Ultrasonic Module attached to the smartphone running the Echo Meter Touch Bat Detector App. Settings used were:

- Save Noise Files: Off
- Real-time Auto ID: On
- Auto-ID Sensitivity: Balanced
- Trigger Sensitivity: Medium
- Trigger Window: 3sec
- Max Trigger Length: 15sec
- Trigger minimum frequency: 12kHz

Except for the two transects in May 2022, which covered only the outskirts of the village, those in the remaining months aimed to cover the whole of the village with between five and six transects being walked each month. Weather conditions (temperature, relative humidity, atmospheric pressure, wind speed and direction, rainfall) were recorded at approximately five-minute intervals using a personal weather station in my garden and uploaded to Weather Underground as station ISOUTHW09 (data available at: <https://www.wunderground.com/dashboard/pws/ISOUTHW09>).

Table 1: Details of transects walked around South Wonston in 2022.

Date	Time (UTC+1)			Temp (°C)*	Transect route**
	Start	End	Sunset		
25 May 22	21:11	21:52	21:03	13.8	OR-GC-SL1-SL2-SWF-SL2-SL-GC-OR
27 May 22	20:58	22:21	21:05	14.5	OR-GC-SL1-SL2-SWF-AD2-VHT-OD-LR3-LR2-LR1-OR
08 Jun 22	21:08	22:38	21:18	14.2	OR-GC-DR2-WW-WHRN-AD2-VHT-LR3-LR2-LR1-OR
11 Jun 22	21:22	22:11	21:20	15.7	OR-GC-SL1-SL2-SWF-SL2-SL1-OR
17 Jun 22	21:21	22:07	21:23	21.8	OR-GC-SL1-SL2-SWF-SL2-SL1-OR
22 Jun 22	21:14	22:10	21:24	19.9	OR-GC-SL1-SL2-SWF-SL3-SWF-SL2-SL1-OR
29 Jun 22	21:28	22:25	21:24	14.2	OR-DR1-CH1-CH2-WT-CH2-DR1-OR
06 Jul 22	21:23	22:26	21:21	18.7	OR-GC-SL1-SL2-SWF-SL2-SR-MR-DR1-CH2-LR1-OR
07 July22	21:34	22:50	21:21	18.4	OR-DC-SL1-SL2-SWF-AD1-WN-WHRN-DR3-Dr2-DR1-OR
11 Jul 22	21:25	22:39	21:18	20.8	OR-DW1-LR2-LR3-OD-VHT-AD2-WHRN-WW-DR2-DR-1-OR
12 Jul 22	21:26	22:10	21:17	23.3	OR-GC-SL1-SL2-SWF-SL2-DR1-OR
15 Jul 22	21:14	22:27	21:14	19.3	OR-LR1-LR2-PFS-ST-LR3-DD-WHRS-DR3-DW2-DW1-OR
21 Jul 22	21:21	22:16	21:08	20.8	OR-GC-SL1-SL2-SWF-SL2-SL1-DR2-DW2-DW1-OR
01 Aug 22	20:49	22:12	20:52	21.2	OR-GC-SL1-SL2-SWF-SL3-SWF-SL2-SL1-GC-DW1-DW2-DR2-DR1-OR
02 Aug 22	21:13	22:05	20:50	20.2	OR-GC-DR2-WW-WHRN-A-WHRN-DR1-DW2-DW1-OR
09 Aug 22	20:41	21:54	20:38	22.1	OR-DW1-DW2-LR2-LR1-OD-VHT-AD2-WHRN-WW-DW2-DW1-OR
11 Aug 22	20:42	21:47	20:35	24.6	OR-GC-SL1-SL2-SWF-SL2-SI1-SR-MR-DR1-CH1-CH2-LR-OR
12 Aug 22	20:58	21:43	20:23	25.7	OR-GC-DR2-DR1-WHRN-WD-WHRS-DR1-DW2-DW1-OR
19 Aug 22	20:29	21:34	20:19	17.3	OR-GC-SL1-SL2-SWF-AD1-A-WN-A-WHRN-WW-DW2-DW1-OR

Notes: * At the start of transect. ** See Figure 1 for locations.

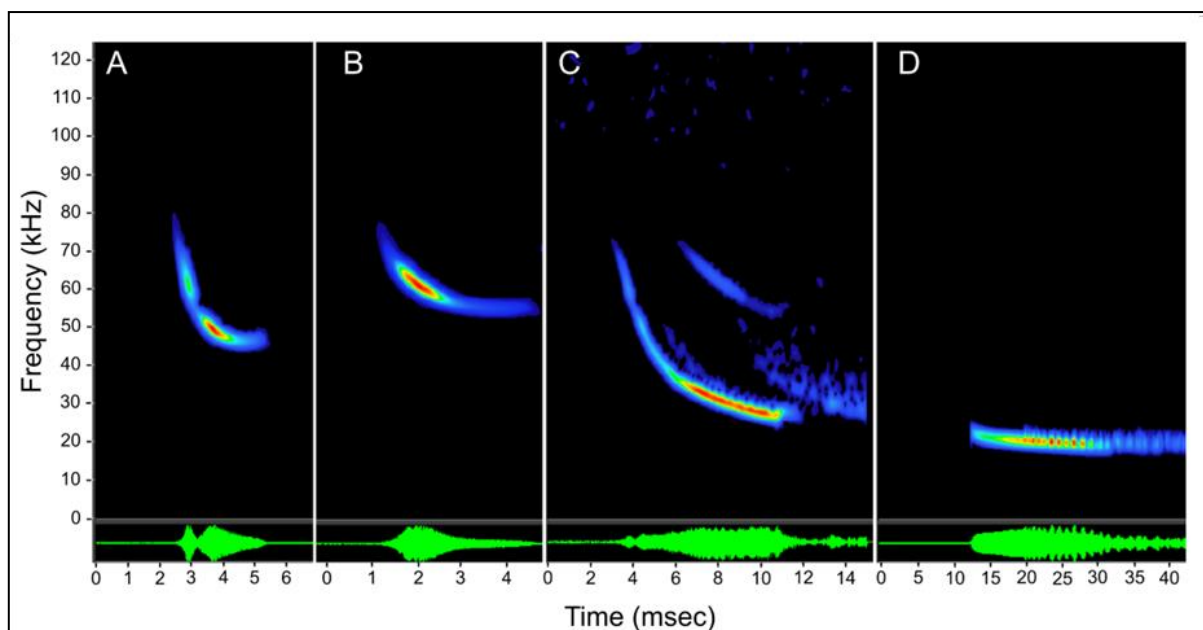


Figure 3: Example single call sonograms of bat species recorded during the survey. (A) common pipistrelle; (B) soprano pipistrelle; (C) serotine; (D) noctule. Note that the time scales on the X-axis are different for the four sonograms.

Data analysis

High-quality echolocation call recordings were analysed using Sonobat 30 and the UK South region pack for initial identification. This was followed by manual vetting using species' call characteristics (Russ, 2021) to confirm the automatic identifications. Representative sonograms of single calls from the four recorded species are shown in Figure 3.

ArcGIS Online (<https://www.arcgis.com/home/index.html>) was used for the geospatial analysis of the metadata of the bat recordings and the development of a web application to visualise the survey data.

Survey limitations

Unfortunately, the survey suffered from several limitations and biases. In particular, some areas of the village were visited more often than others, despite attempts to cover all areas more or less equally during the months of June to August. This was the consequence of two conflicting needs: the collection of echolocation recordings for detailed call analysis and the broader survey of bat activity around the village. Consequently, there was a (subconscious) tendency to re-visit places of known activity. As with all transect surveys, recordings were made at single locations along the transect and, therefore, activity elsewhere would have been missed. This is important given the different emergence times of the bat species and resulted in recordings being made at progressively later times relative to sunset along a transect as it was walked. Finally, any recordings identified by the detector as being noise were not saved and thus it is possible that some faint/noisy call sequences were lost. Notwithstanding these limitations, it is considered that the data collected during the survey provides an indication of relative bat activity around the village, although statistically significant inferences are not really possible.

Results

Species observed during the transects

From the 19 transects, 610 high-quality call sequences were recorded and identified as corresponding to four species of bat:

- common pipistrelle (490 call sequences, 80.3%)
- soprano pipistrelle (15 call sequences, 2.5.0%)
- noctule (67 call sequences, 11.0%)
- serotine (38 call sequences, 6.2%)

In percentage terms, the common pipistrelle was the main species encountered and the relative proportion of the remaining species was broadly comparable to those observed in 2018-2021. No call sequences were recorded corresponding to brown long-eared bat or Nathusius' pipistrelle, which had been observed previously.

The spatial distribution of all the bat recordings is shown in Figure 4 as clustered pie charts reflecting both the number and types of bats encountered, and broadly follows the distribution observed in 2018-2021. 'Hot spots' of activity are mainly along tracks outside the built-up area of the village to the north and east. Approximately 60% of the call sequences were recorded around South Wonston Farm (location SWF) and the tracks that lead away to the northwest, east, and south (SL3, AD1 and SL2 respectively).

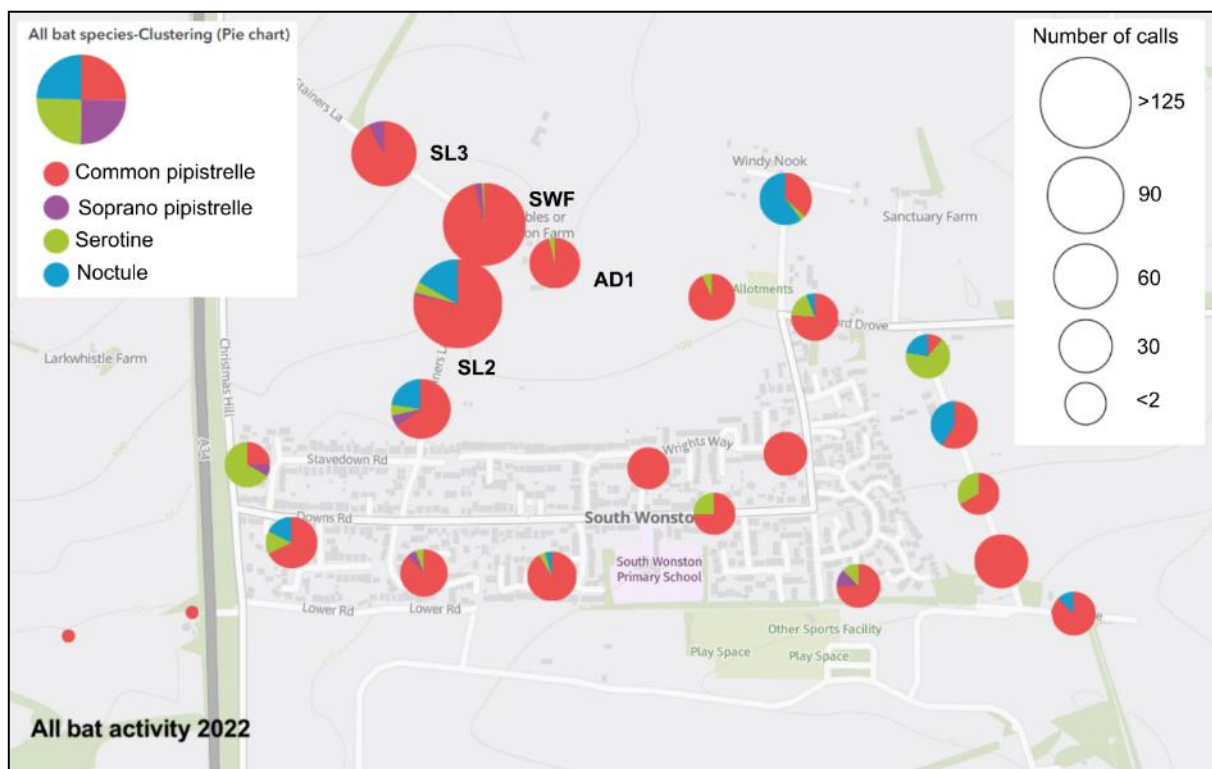


Figure 4: Distribution of all bat echolocation call sequence recordings made during the 2022 survey. Clustered pie charts show both the relative number of call sequences and the proportion of species recorded. ESRI GB Background basemap contains OS data © Crown Copyright and database rights 2022.

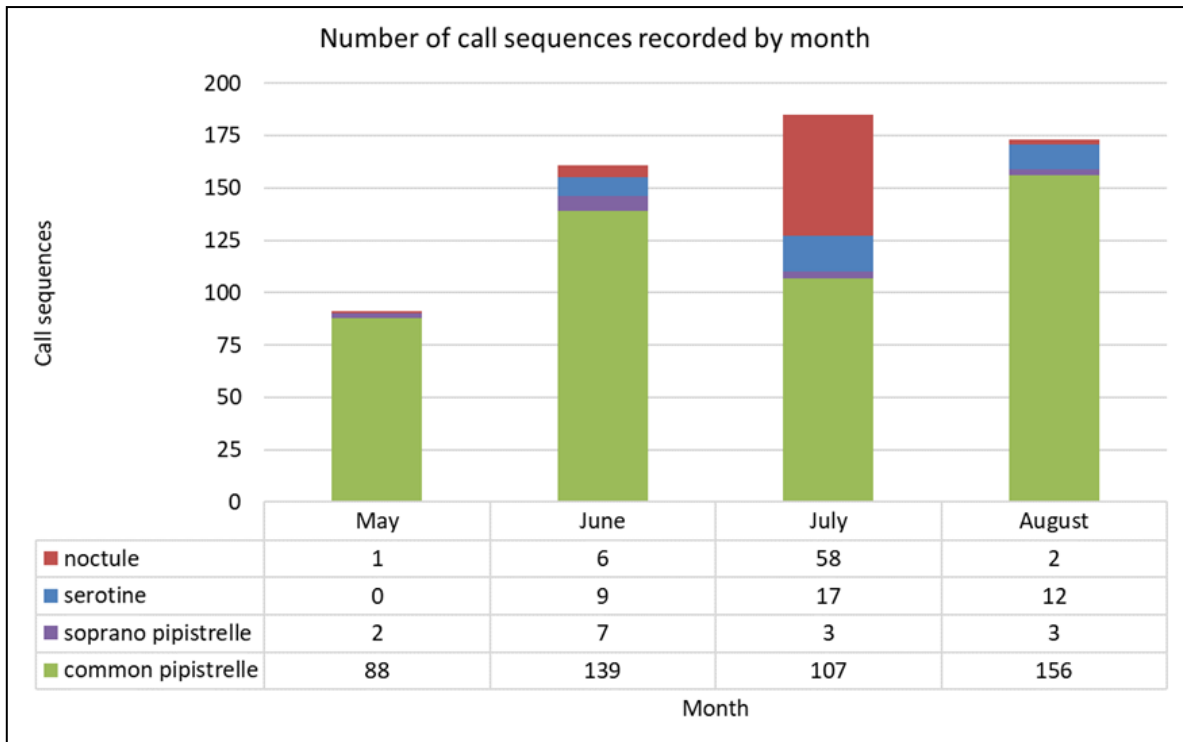


Figure 5: Distribution of call sequences recorded during the survey.

Temporal distribution of bat species

Apart from the month of May, when only three species were recorded during the two transects walked towards the end of the month, call sequences from all four bat species were recorded in the following months, albeit to varying abundances (Figure 5). Whilst relative activity in June and August was broadly similar, July was characterised by a large increase in the number of noctule call sequences recorded and a reduction in the number of common pipistrelle sequences recorded. Normalising the data to consider the number of transects walked during these months did not significantly alter the relative levels of activity.

Spatial distribution of bat activity

The spatial distributions of the call sequences for the four bat species recorded during the survey are shown in Figures 6 – 9. Points show the locations of the recordings and the numbers indicate the total call sequences recorded in their respective 100 x 150m boxes (although in reality they are restricted to the roads and tracks that pass through the boxes).

Common pipistrelle

Whilst approximately 17% of the common pipistrelle call sequences were recorded within the built-up area of the village, the vast majority (69%) were recorded to the north of the village around South Wonston farm (SWF) and along the tracks leading away from it (Figure 6). The north-south track to the east of the village between Alresford Drove and the Ox Drove (VHT) represents a second ‘hot spot’ of activity with approximately 9% of the call sequences being recorded there. Only a few call sequences were recorded to the immediate south of the village. Whilst this area includes some trees and hedges along the Ox Drove (OD) towards the eastern end of the village, most of the area to the south comprises open arable fields.

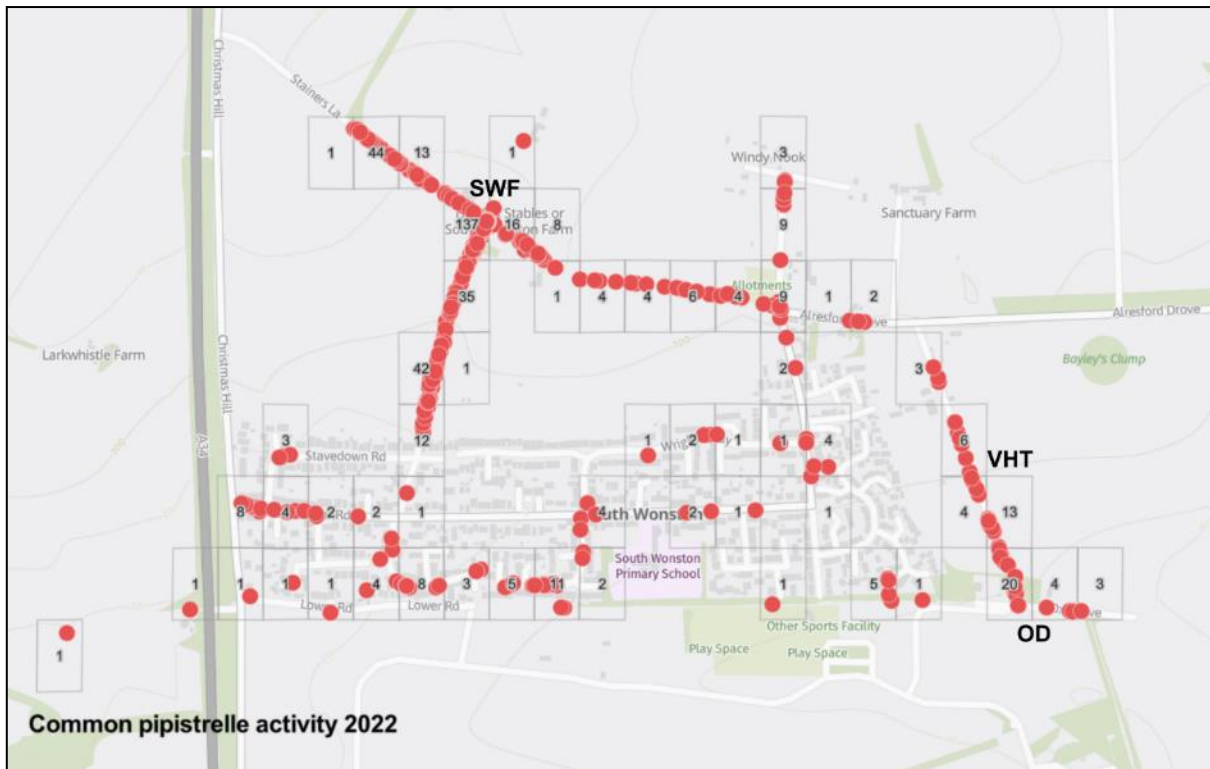


Figure 6: Distribution of common pipistrelle call sequences recorded during the 2022 survey. Numbers show the total number of call sequences in their respective rectangles. ESRI GB Background basemap contains OS data © Crown Copyright and database rights 2022.



Figure 7: Distribution of soprano pipistrelle call sequences recorded during the 2022 survey. Numbers show the total number of call sequences in their respective rectangles. ESRI GB Background basemap contains OS data © Crown Copyright and database rights 2022.

Serotine activity 2022

Volume Four 2023

Soprano pipistrelle

Although only a handful of soprano pipistrelle call sequences were recorded, most of the activity was located to the north of the village around South Wonston farm (SWF) and along the tracks leading away from it (Figure 7). Except for isolated call sequences, no significant activity was recorded to the west, south and east of the village.

Noctule

Most of the noctule call sequences (55%) were recorded in the western part of the village and along Stainers Lane track (SL2) leading to South Wonston Farm (Figure 8). Additional 'hot spots' of activity were recorded at Windy Nook (WN) and on the north-south track to the east of the village between Alresford Drove and the Ox Drove (VHT).

Serotine

Serotine activity was mainly recorded on the western edge of the village along Christmas Hill road (CH1), on Stainers Lane track leading to South Wonston Farm (SL2), and around Alresford Drove (AD2) to the northeast of the village (Figure 9).

Feeding buzzes

Nineteen feeding buzzes from three of the species were identified in the 610 call sequence recordings:

- common pipistrelle (10 feeding buzzes, 52.6%)
- noctule (five feeding buzzes, 26.3%)
- serotine (four feeding buzzes, 21.1%)

Many of the feeding buzzes (50%) were located around South Wonston Farm (SWF) and Stainers Lane track leading away to the south (SL2) (Figure 10).

MACAROON – an interactive web application

One limitation of a 'static' article like this one is that it can be difficult to show the complexity of the data and analysis without the recourse to a plethora of figures and tables. Single points can also become easily hidden amongst clusters of points on the maps. To address these issues, a web application called 'MACAROON' (a somewhat forced acronym for 'MApping bat aCtivity ARound south wOnstON') has been developed using the Instant Apps capability of ArcGIS Online. The application dynamically displays the geospatially referenced call sequence metadata collected during the survey in a web browser and can be freely accessed online at <https://arcg.is/izy1T0>. A screenshot of the interface to the application is shown in Figure 11.

Besides the maps presented in this article, the MACAROON web app includes:

- The distribution of all call sequences by each month
- A heat map of all bat activity
- Bookmarks to zoom into particular locations around the village

The user can turn the various layers on and off, zoom in and out, pan around the map, change the background and click on a point to see further details of the underlying data.

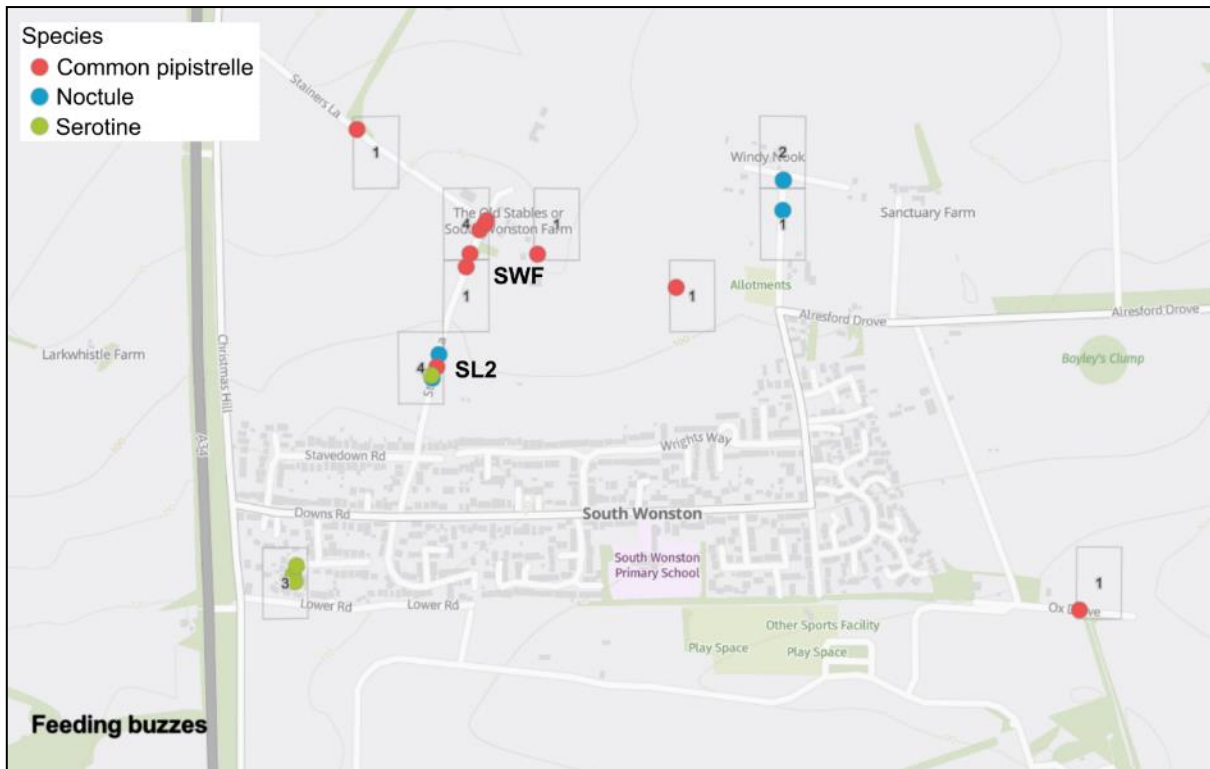


Figure 10: Distribution of feeding buzzes identified during the 2022 survey. Numbers show the total number of call sequences in their respective rectangles. ESRI GB Background basemap contains OS data © Crown Copyright and database rights 2022.

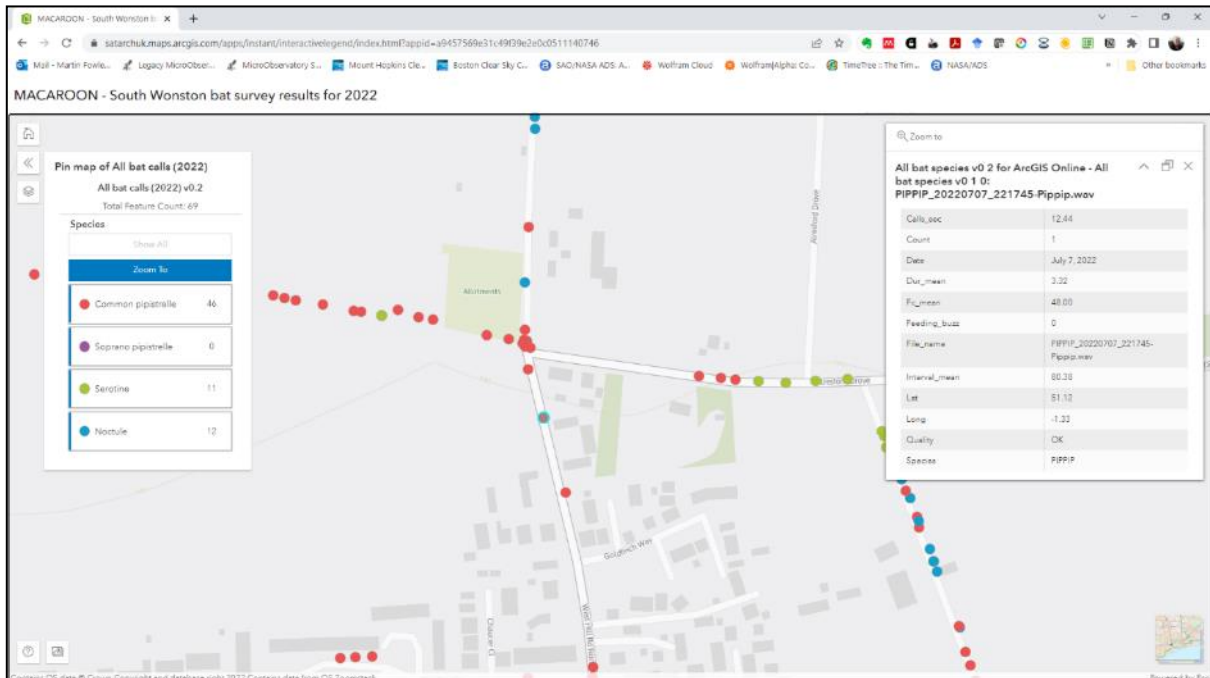


Figure 11: Screenshot of the MACAROON web application. A single common pipistrelle observation in the centre of the screen has been selected and details of the call sequence metadata are shown in the pop-up box to the right. ESRI GB Background basemap contains OS data © Crown Copyright and database rights 2022.

Discussion

The four species of bats identified from their echolocation calls (common pipistrelle, soprano pipistrelle, noctule and serotine) confirm previous observations of these species around the village of South Wonston in 2018-2021. However, despite some 610 call sequences being recorded, no calls were identified from brown long-eared bat and Nathusius' pipistrelle. These species were single observations identified from call sequences recorded in July 2018 and June 2020 respectively. Whilst they may represent a relatively small number of individuals that were missed during the 2022 survey, it is also possible that the species are no longer active around the village.

In relative terms, the common pipistrelle was the main species encountered during the survey, whereas the soprano pipistrelle was by far the least abundant activity. However, the latter may represent an underestimate, as it has been demonstrated that call plasticity can result in soprano pipistrelles occasionally producing echolocation calls with the characteristics of their lower frequency siblings (Montauban *et al.*, 2021). Noctule were the second-most abundant species recorded followed by serotine.

Call sequences from all four bat species were recorded in the months of June to August, albeit with varying relative degrees of abundance. The month of July was characterised by an increase in the number of noctule call sequences recorded and a reduction in the number of common pipistrelle sequences compared with the previous and following months. Whilst it is noteworthy that July 2022 was provisionally the driest July for Southern England and had mean temperatures well above normal (Bowker, 2022), in the absence of a baseline from previous years it is possible that the different levels of observed activity reflect the survey biases described above rather than true changes in activity.

The vast majority of common pipistrelle call sequences, and many of the soprano pipistrelle calls, were recorded to the north of the village around South Wonston farm and along the tracks leading away from it. This area of grazing fields is rich in trees and hedges, and the high level of activity suggests a common pipistrelle roost site in the vicinity. Noctule call sequences were recorded in the western part of the village, to the north around South Wonston Farm and to the east of the village. Serotine activity was mainly recorded on the western edge of the village, on Stainers Lane leading to South Wonston Farm and to the northeast of the village. Whilst the differences in the spatial distribution of the noctule and serotine call sequences hint at some segregation of the species' activity, further work is clearly required to investigate both the spatial and temporal variations of bat activity around the village.

The observation that feeding buzzes were present in only 3% of the call sequences recorded suggests that the bats that were encountered were primarily commuting rather than feeding. No social calls were identified in the call sequence recordings although this is perhaps not surprising as the survey was largely conducted between the two 'seasons' for common pipistrelle social call activity of April/May and September (Middleton *et al.*, 2014, 20–21).

Conclusions

Despite its limitations, the survey has successfully identified the main bat species that were active around the village of South Wonston in 2022 and has hinted at both temporal and spatial variations in their activity. The development of the MACAROON web application provides a useful way to display the survey results and complements this article with additional views of the data. Further work is planned to be undertaken in 2023 to address the biases in the survey and to further investigate the temporal and spatial variations in bat activity around the village.

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Acoustic Nathusius' pipistrelle migration study on the Dorset coast, autumn 2017

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Introduction

I first recorded the calls of Nathusius' pipistrelle *Pipistrellus nathusii* at Longham Lakes, north of Bournemouth, Dorset, on a series of visits through the summer of 2016. Reading about the species, I learnt that they were considered to be rare in the United Kingdom, that their summer range was centred around the Baltic and that they were known to migrate west in the autumn, along the French Channel coast and south as far as Spain.

As the Nathusius' pipistrelle at Longham Lakes were present through the summer, they were presumably resident there. The recapture of bats ringed on the Latvian coast suggested that some Nathusius' pipistrelle migrate to the United Kingdom in the autumn (Figure 1). In 2018 a bat ringed in the United Kingdom was recovered in Belgium (Bat Conservation Trust, 2018).

I wanted to know whether Nathusius' pipistrelle migrate west along the Dorset coast in the autumn.

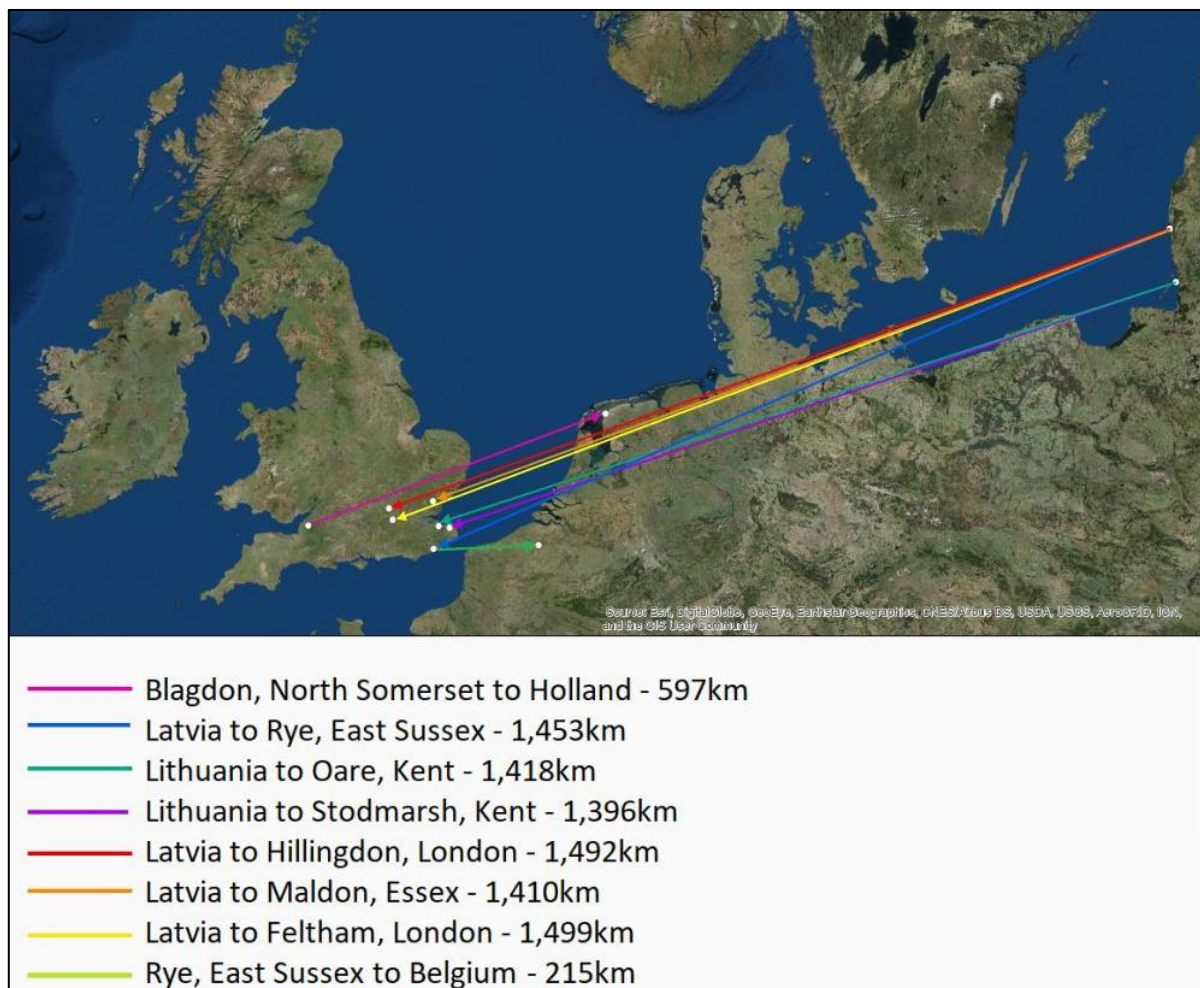


Figure 1: Movements and distances covered by Nathusius' pipistrelle (Bat Conservation Trust, 2018).

Method

With limited resources, the only option was an acoustic survey using a single SM4BAT full spectrum static bat detector.

Not knowing when the bats migrate, the plan was to continue the survey from mid-August through into November. Extending the duration of the survey would also show background activity levels if Nathusius' pipistrelle were resident in the survey area.

Where to place the detector?

Bat detectors have a limited range as bat echolocation calls attenuate as they pass through air. The bats would have to come close to the detector for this survey to succeed.

The fact that Nathusius' pipistrelles migrate along coastal routes was widely accepted. Promontories act as departure points for migrating bats (Ahlén *et. al*, 2009) so topographical features in the landscape affect the routes chosen.

Were there any topographical features along the Dorset coast that might funnel westbound bats through a gap where a detector could be placed? (Figure 2).

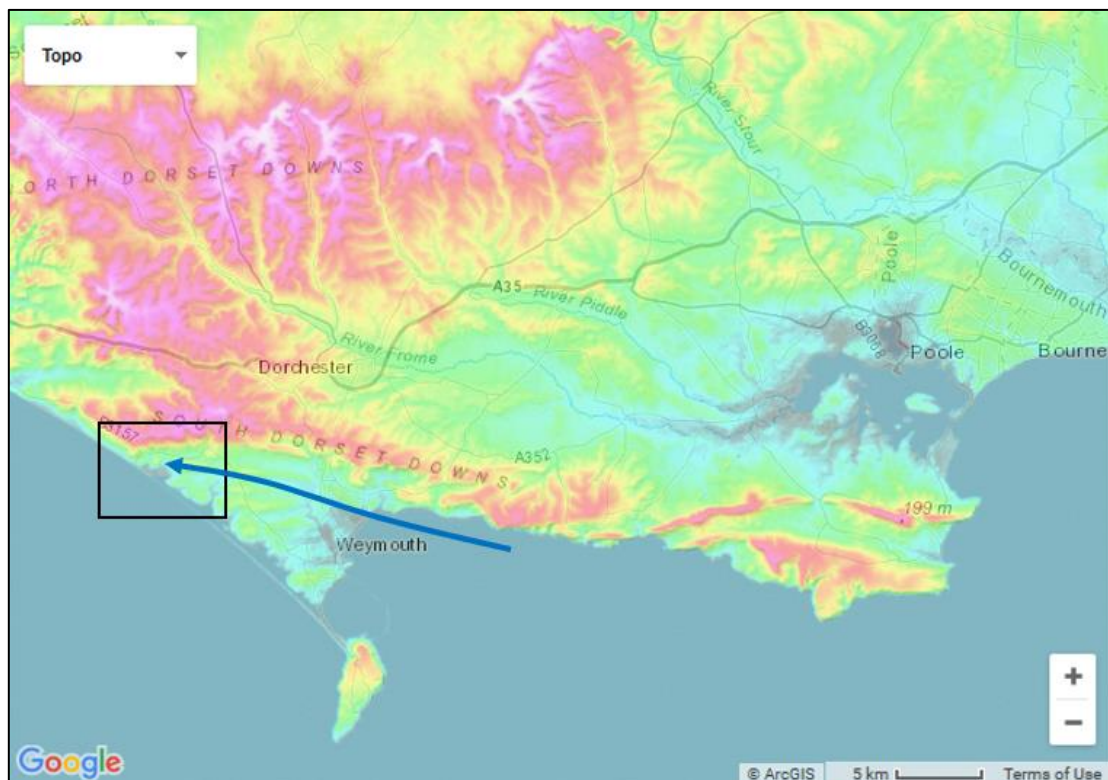


Figure 2: Topographic map of south Dorset (en-gb.topographic-map.com).

The Dorset Ridgeway north of Weymouth rises to around 200m behind Abbotsbury, where it converges with the coast, forming a narrow corridor between the high ground and the crest of Chesil Beach (Figure 3).

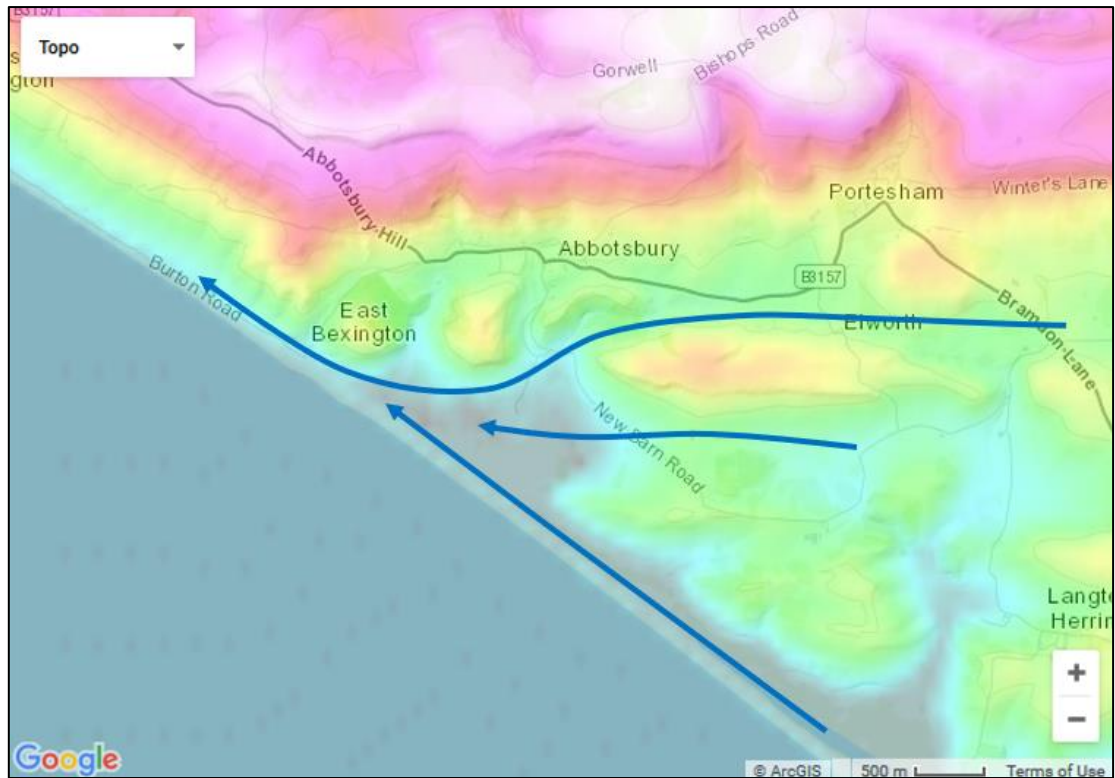


Figure 3: Topographic map of Abbotsbury and Chesil Beach (en-gb.topographic-map.com).

There were few potential locations for a bat detector here, but this tamarisk had a central view of the corridor between the hills and the top of the beach (Figure 4).



Figure 4: The view covered by the SM4BAT full spectrum microphone.

Note that a permit is required from the Ilchester Estates to undertake any survey on this privately owned land.

Analysing the files

The aim was to discover and count all the files that included Nathusius' pipistrelle calls.

In 2017, I reviewed the files manually. Revisiting the data, I used Kaleidoscope Pro as a quick way to highlight the more obvious Nathusius' pipistrelle files using auto-ID. The results file provided a useful basis for further manual review. I followed the steps below, checking files for the presence of Nathusius' pipistrelle calls:

- Ran Kaleidoscope Pro auto-ID, classifier Bats of Europe 5.2.1
- Checked through the files identified as PIPNAT.
- Viewed all the NoID files, manually identifying any with Nathusius' pipistrelle calls.
These files may include calls from more than one species or atypical calls
- Reviewed additional files (not covered above) that were originally flagged in 2017 and marked these as Nathusius' pipistrelle where appropriate.
The calls in many of these files are predominantly from another species (e.g. common pipistrelle P. pipistrellus) but also include Nathusius' pipistrelle calls

Out of the original 15,785 files collected 1,533 (9.7%) included Nathusius' pipistrelle calls (Figure 5).

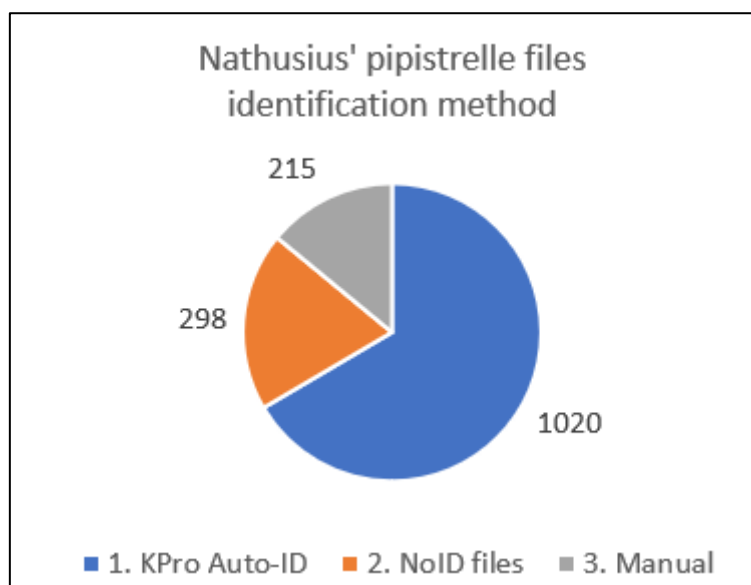


Figure 5: Breakdown of Nathusius' pipistrelle files by identification method.

Results

Files per night

The number of Nathusius' pipistrelle files recorded each night is an indication of the relative levels of activity (Figure 6).

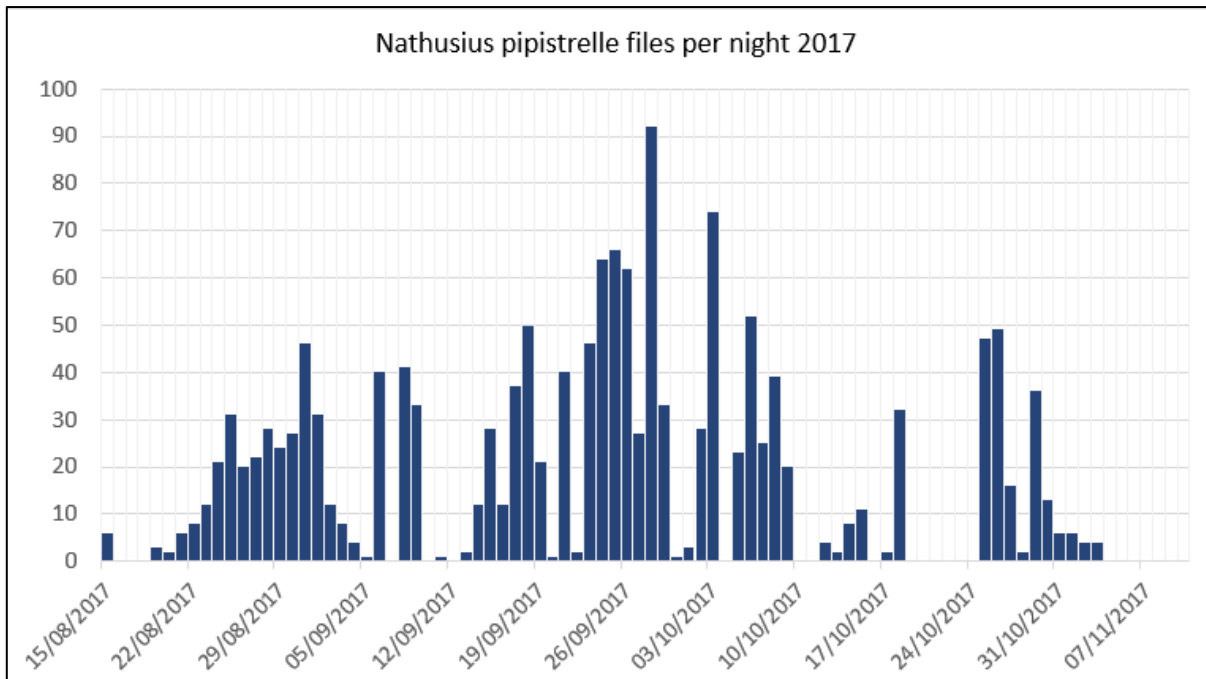


Figure 6: Number of Nathusius' pipistrelle files per night.

The pattern of activity for common pipistrelle was very different (Figure 7).

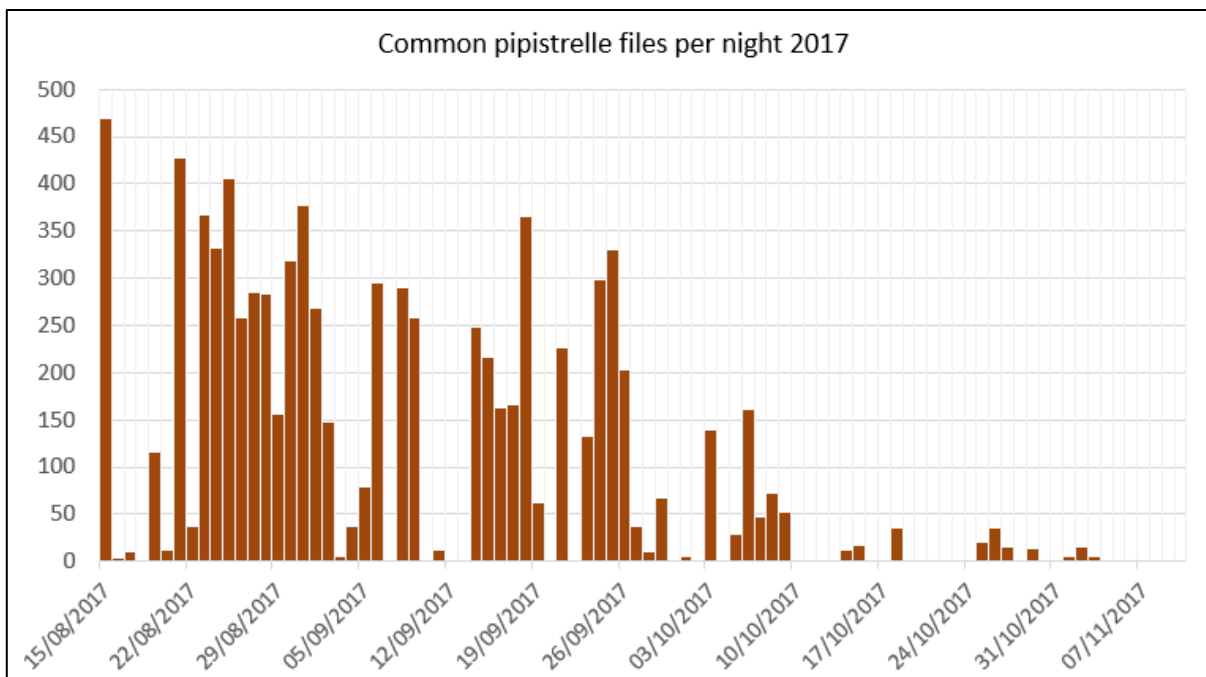


Figure 7: Number of common pipistrelle files per night.

Gaps

Both charts show nights with no bat activity or very low activity. This pattern is seen for both species and is likely to be caused by adverse environmental factors. The back of the beach provides no shelter and is exposed to the full force of the weather, especially the prevailing south westerly winds. In such an exposed location, there would be nights when adverse weather prevents bats from flying.

Note that, on some nights, when no common pipistrelle files were recorded, Nathusius' pipistrelle were still active on the beach (e.g. 13/09/2017, 20/09/2017, 22/09/2017 and 30/09/2017).

The most striking example was on 02/10/2017. No common pipistrelle files were recorded but 28 Nathusius' pipistrelle files were recorded, mostly after midnight. Nathusius' pipistrelle activity during the following night was also exceptionally high compared to common pipistrelle activity.

Trends

From late summer into autumn, the decrease in file numbers for common pipistrelle was expected. The largest number of files was recorded on 15/08/2017. After mid-October, activity was minimal and sporadic.

In contrast, Nathusius' pipistrelle file numbers were low at the start of the survey. File numbers built up from 20/08/2017 to a peak in late September, were still high at the end of October then decreased to 03/11/2017.

Timing of activity

Figure 8 shows how the numbers of Nathusius' pipistrelle files were spread through the night. Hour zero starts at sunset:

- The first six hours after sunset are coloured from yellow to dark brown
- The last two hours before sunrise are coloured blue
- The gap between the two is shown in grey. This gap lasts only 1 hour 28 minutes on 15/08/2017 but increases to 5 hours 35 minutes by 07/11/2017

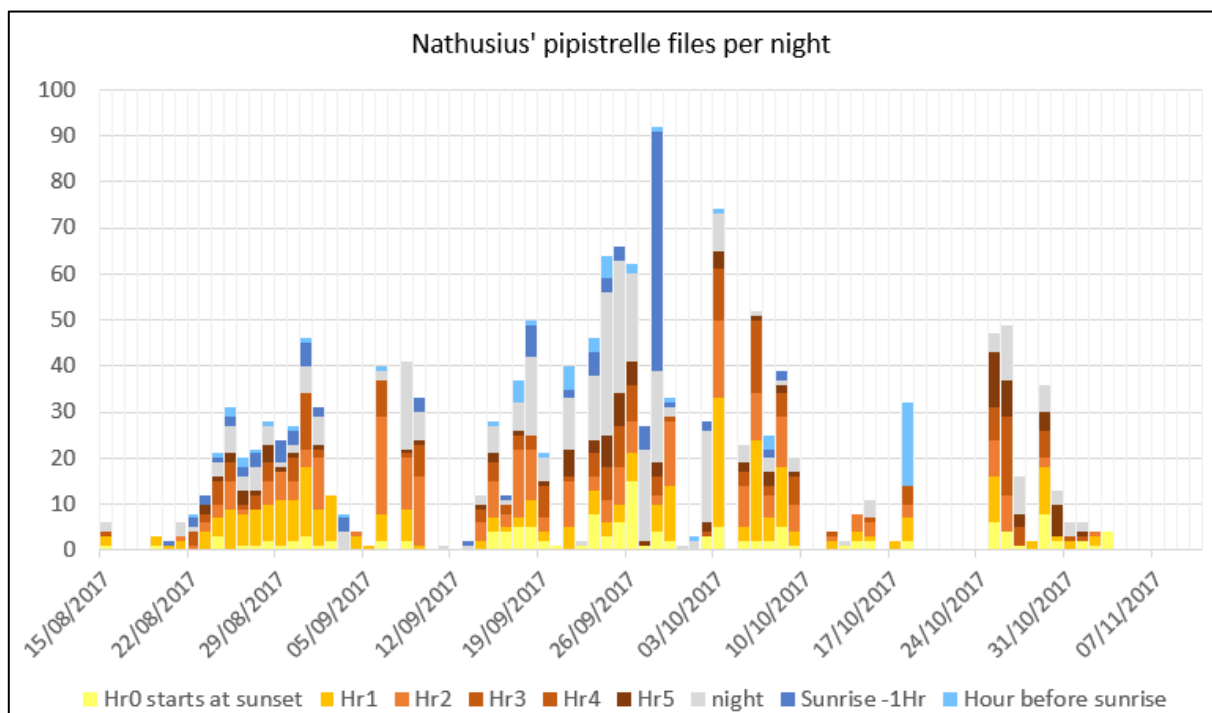


Figure 8: Number of Nathusius' pipistrelle files by hour after sunset and before sunrise.

This pattern of activity does not suggest that there is a nearby roost as that would normally produce consistently high levels of activity soon after sunset and again before sunrise as bats returned to the roost. Appendix A details the hourly file numbers and compares the patterns during each phase of the survey.

In summary, the highest levels of activity fell between one and three hours after sunset through most of the survey period, and rather later during the final phase in late October. There was very little evidence of activity before dawn, with two exceptions. By late October, when the nights lasted over 14 hours, almost all the activity occurred within the first six hours after sunset with none within two hours of dawn. This was almost true right through from early October with only a few exceptional nights which had activity before sunrise.

Social calls

Many of the *Nathusius' pipistrelle* files included their distinctive social calls (Figures 9 and 10). This was unexpected. The spectrograms showed that, in all cases, these calls were made by bats flying through the area rather than from fixed song posts. The amplitude of the social calls (always much louder than the echolocation calls) started low, building to a peak as the bat flew closer to the detector then reduced in amplitude as the bat passed and flew away from the detector (Figure 11). There were no structures within detector range that could act as song posts. Bats flying along the valley at the back of the beach would be expected to fly towards the centrally placed detector then continue beyond the detector. The detector stayed in the same place.

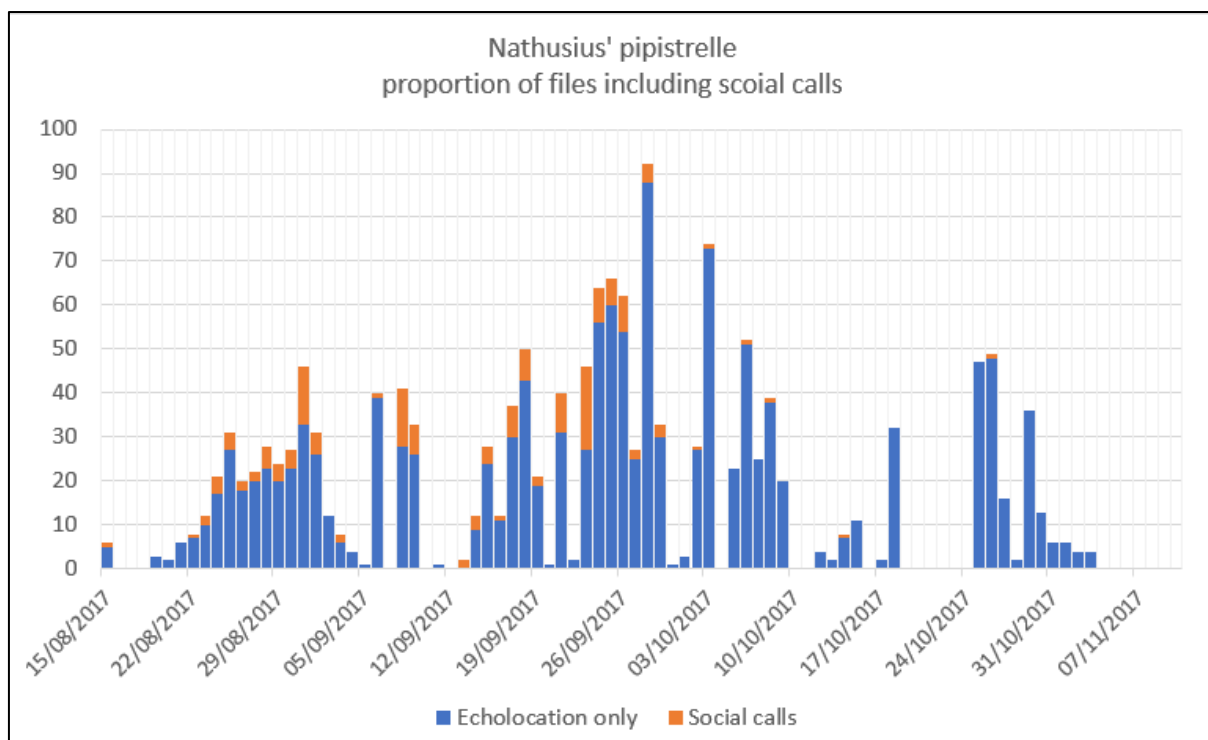


Figure 9: *Nathusius' pipistrelle* files per night showing the split between those that included social calls and those that did not.

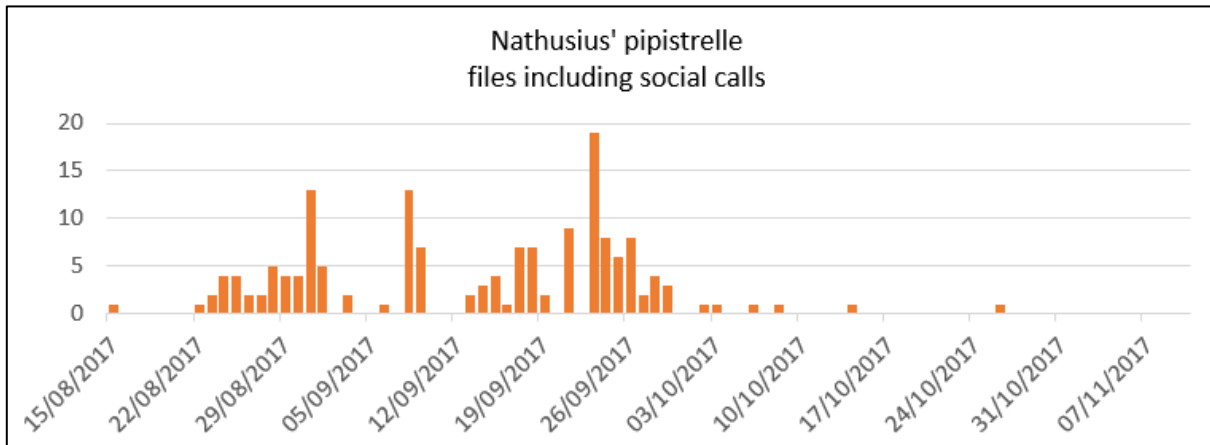


Figure 10: Numbers of Nathusius' pipistrelle files which included social calls. These files were recorded predominantly from 22/08/2017 to the end of September.

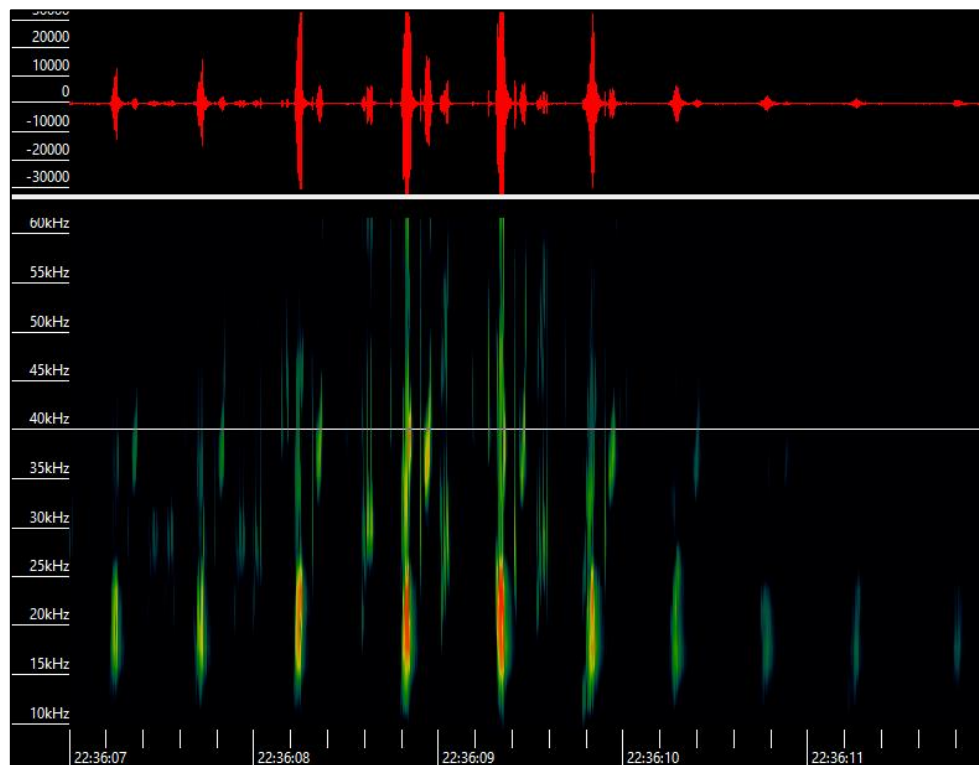


Figure 11: The changing amplitude of Nathusius' pipistrelle social calls as the bat flew towards then past the detector.

Discussion

It is hard to draw firm conclusions from this study. Proving that Nathusius' pipistrelle bats migrated past a point on the Dorset coast in autumn 2017 using a single bat detector is like trying to prove bird migration from one observer's sightings. However, the bat detector did monitor Nathusius' pipistrelle activity at one location from before sunset to after sunrise for 130 successive nights, allowing a comparison of nightly activity levels.

Nathusius' pipistrelle bats were present on the back of Chesil Beach from 15/08/2017 to 03/11/2017. But is there evidence that this activity was due to bat migration? The evidence is circumstantial.

Why would bats be found here at the back of Chesil Beach?

The detector was in a very exposed location, just 80m from the sea. There was no shelter from the prevailing south westerly winds, other than a single 3m high tamarisk bush. Feeding opportunities seemed limited but there may be roosting opportunities at the nearby cottages, 100m and 150m further west along the road or near the Abbotsbury Swannery 2km further to the east.

The survey location was not likely to be a destination in its own right for these bats. It is also unlikely that these bats were flying at right angles to the valley along the back of the beach as there is a steep hill to one side and shingle and sea to the other. It seems very probable that the calls recorded were from bats that flew along the valley at the back of the beach e.g. to and from roosts, commuting along the coast or on migration.

Changes in nightly activity levels

Common pipistrelle proved to be the dominant species in this location with 8,442 files recorded during the survey period. As expected, the number of files recorded each night started high with 468 files recorded on 15/08/2017 and diminished progressively to 51 files recorded by 09/10/2017.

In contrast, the Nathusius' pipistrelle file numbers started low, with six files recorded on 15/08/2017, increased to a peak in late September with over 60 files a night from 24/09/2017 to 26/09/2017. File numbers were still high at the end of October, with 47 and 49 files recorded on 25/10/2017 and 26/10/2017, continuing through into early November with the last files recorded on 03/11/2017.

When designing this survey it was anticipated that, if Nathusius' pipistrelle bats migrated west along the Dorset coast in autumn in significant numbers, the numbers of files recorded at this location would start low, build to a peak and then decrease later in the season. This was the pattern observed.

Breaks in activity

Nights with no Nathusius' pipistrelle activity match those for common pipistrelle, suggesting that environmental conditions, such as adverse weather, prevented both common and Nathusius' pipistrelle from flying along the beach on some nights.

Between 19/08/2017 and 03/11/2017, no common pipistrelle files were recorded on 24 nights. In contrast, no Nathusius' pipistrelles files were recorded on just 13 of these nights. So, there were 11 nights when, of these two species, only Nathusius' pipistrelles were recorded on the beach.

The larger Nathusius' pipistrelle may be able to fly in rougher weather. Another explanation is that Nathusius' pipistrelle are strongly motivated to continue their migration west along the coast while common pipistrelle have no need to fly along the back of the beach and may choose easier, more sheltered local foraging areas on rough nights.

How is activity spread through the night?

If the Nathusius' pipistrelle recorded by the detector were using nearby roosts, there would

be high levels of activity during the first hour after sunset (Hr0) and, less predictably, before sunrise. Figure 8 does not show this pattern of activity.

Through most of the survey period, the highest activity levels occurred between one and three hours after sunset. This would be consistent with bats flying a significant distance before arriving at this location.

High activity after nights with low or no activity

The survey location, the whole of Chesil Beach and The Fleet that lies behind it are exceptionally exposed. On nights where Nathusius' pipistrelle are unable to fly along Chesil Beach, other bats may be able to make progress further back along the migration route. This suggests that an increasing number of Nathusius' pipistrelle bats may be bottled up in sheltered locations, waiting for the weather to change to allow them to progress along this exposed section of coast.

If this is correct, higher levels of activity would be expected after nights with low activity. This may account for some of the high number of files recorded, on 03/10/2017 in particular.

Direction of flight

The original analysis of the files from this survey attempted to establish the direction of flight (from in front of the detector or from behind it) by analysing the acoustic details of the calls in each pass. Using the changing incidence of echoes, from the foliage on the tamarisk bush behind the microphone and the changing amplitudes, the direction of flight could be established for some of the files with confidence.

However, the assessment is subjective and hard to apply consistently. Many files have calls that are too faint or indistinct for analysis. Consequently, directional analysis not been included in this report.

High numbers of social calls

Over many hours listening to Nathusius' pipistrelle calls in the field, I had never heard their distinctive social calls. Finding social calls in 161 (10.5%) of the 1,533 Nathusius' pipistrelle files recorded over 130 autumn nights on Chesil Beach was a surprise.

In all the files that included a series of social calls, it was clear that the calls were made in flight, as the bat flew towards then away from the microphone, determined by the changing amplitude of the calls.

In many of the files, it was also clear from their echolocation calls that two or more Nathusius' pipistrelle bats were flying past the microphone at the same time.

The survey location was chosen in the hope that the topography would funnel migrating bats together and channel them along the back of the beach. The numbers of files recorded confirms that many Nathusius' pipistrelle fly along this route. Many of the files show multiple bats passing through at the same time. It seems likely that the close proximity of bats, within earshot of each other, triggers social calling by the males.

Figures 12 and 13 show Nathusius' pipistrelle social calls recorded during the survey. The first spectrogram is typical (Figure 12). The third part of each phrase, the rising trill, is distinctive and often stands out in a spectrogram. Calls after the rising trill are variable and often absent.

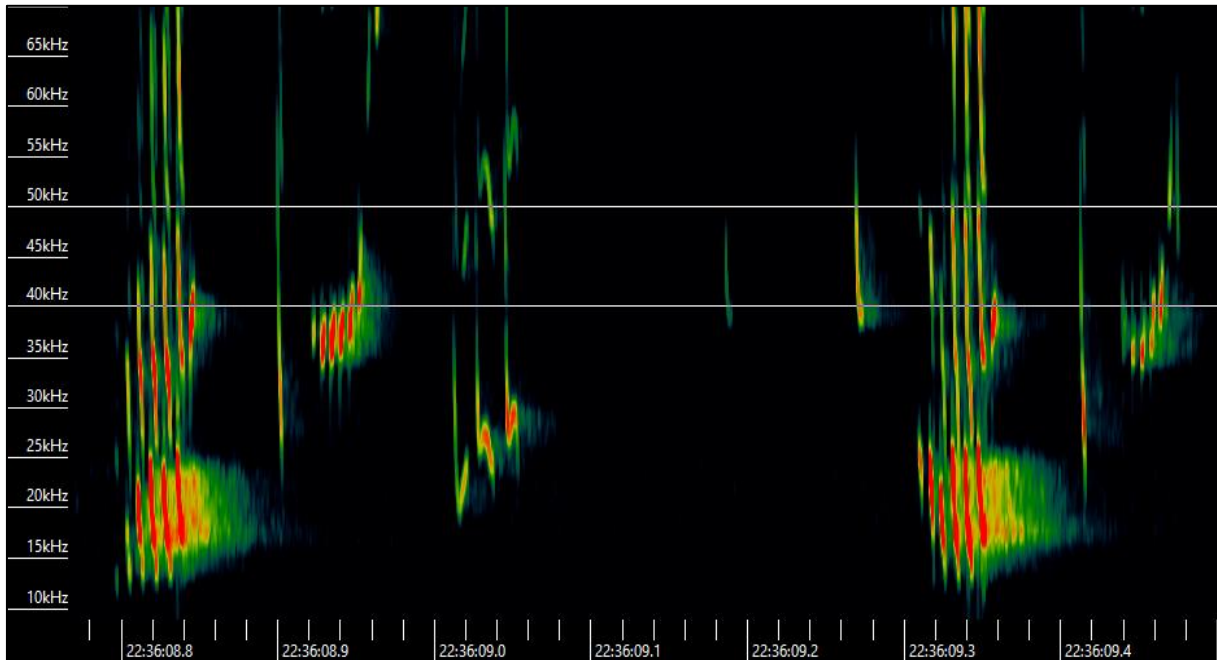


Figure 12: Typical Nathusius' pipistrelle social call.

The second example shows more variety as two Nathusius' pipistrelle call at each other; note that two different social calls overlap in the centre of the spectrogram (Figure 13).

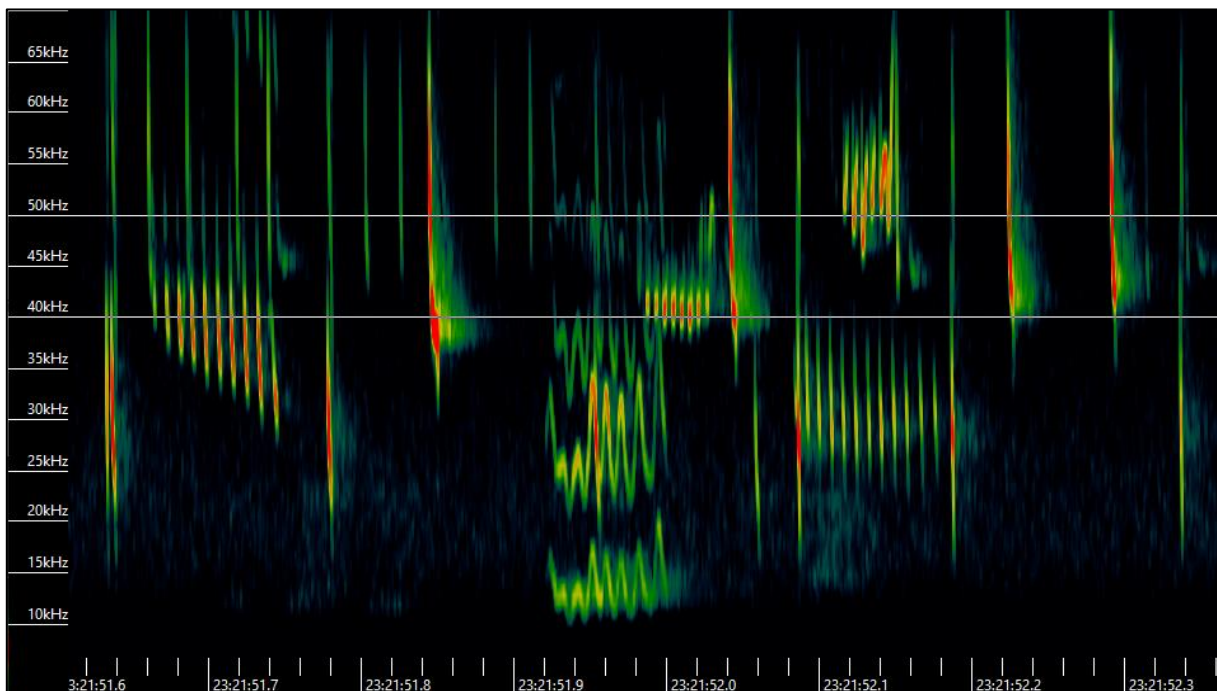


Figure 13: Less typical Nathusius' pipistrelle social calls; two bats calling together.

Conclusion

The pattern of activity suggests that *Nathusius'* pipistrelle did migrate west along Chesil Beach near Abbotsbury during autumn 2017.

Activity built up from 15/08/2017 to a peak late in September then fell away through October into early November. The local topography did apparently channel the bats along the back of the beach, between the sea and the high ground. This seems the only likely explanation for the large number of *Nathusius'* pipistrelle files recorded. This funnelling effect brought bats into close contact, eliciting social calls from *Nathusius'* pipistrelles flying through together.

Further Research

Repeatability

Rerun the survey in future years to establish whether activity follows the same pattern. If it differs significantly, how does it differ?

Repeat the survey at other locations, if suitable locations can be found. If the patterns are similar along the south coast this gives greater confidence that the pattern here on Chesil Beach represents migration activity and does not result from local factors.

Effects of Weather

Compare activity levels with local weather conditions in order to understand which conditions favour *Nathusius'* pipistrelle activity and which prevent activity on Chesil Beach.

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Appendix A

File numbers per hour after sunset

From personal observation, *Nathusius'* pipistrelles emerge from their roosts and start foraging soon after sunset, much like common and soprano pipistrelles. Any locally roosting bats were expected on the back of the beach soon after sunset. Bats on migration might arrive at any time through the night, depending on distance travelled.

Phase 1

Up to 31/08/2017, the largest number of files fall in Hr1, with a hint of returning bats in Hr9. From 06/09/2017, the highest numbers move out to Hr2 (Table 1).

Table 1: Phase 1. Number of Nathusius' pipistrelle files recorded each hour after sunset. Hour zero starts at sunset. Daylight hours are highlighted with a pale yellow background.

Files:	Hr0	Hr1	Hr2	Hr3	Hr4	Hr5	Hr6	Hr7	Hr8	Hr9	Hr10	Hr11	Hr12	Hr13
15/08/2017	1	2		1			2							
16/08/2017														
17/08/2017														
18/08/2017														
19/08/2017	1	2												
20/08/2017		1							1					
21/08/2017		2	1				2	1						
22/08/2017			1	1	2			1	2	1				
23/08/2017		4	2	1	1	2			2					
24/08/2017	3	4	3	2	3	1	2	1	1	1				
25/08/2017		9	6	2	2	2	3	3	2	2				
26/08/2017	1	7	1		1	3	1	2	2	2				
27/08/2017	1	8		1	2	1	1	2	5	1				
28/08/2017	2	8	5	2	2	4	2		2	1				
29/08/2017	1	10	6			1		1	1	4				
30/08/2017	2	9	4	4	1	1	1	1	1	3				
31/08/2017	3	15	4	9	3		1	2	5	4				
01/09/2017	1	8	11	1	1	1	1	3	2	2				
02/09/2017	2	10												
03/09/2017								3	3	2				
04/09/2017		3	1											
05/09/2017		1												
06/09/2017	2	6	21	8				1	1		1			
07/09/2017														
08/09/2017	2	7	11		1	1	4		15					
09/09/2017		1	15	4	3	1	2	1	3	3				
10/09/2017														
11/09/2017								1						
12/09/2017														

Phase 2

High file numbers in Hr1 and/or Hr2 are followed by a lull in Hr3 and then a second wave of activity later in the night (Table 2). There is little to suggest bats returning to a roost before dawn.

Many of the files in Hr10 on 28/09/2017 include feeding calls. The availability of a food resource along the back of the beach may accounts for the high levels of activity during this hour.

There are high levels of activity soon after sunset on 03/10/2017 and 06/10/2017 following nights with little or no activity. Migrating bats may be held back by bad weather and have to wait until conditions improve before they can continue west along the beach.

Table 2: Phase 2. Number of Nathusius' pipistrelle files recorded each hour after sunset. Hour zero starts at sunset. Daylight hours are highlighted with a pale yellow background.

Files:	Hr0	Hr1	Hr2	Hr3	Hr4	Hr5	Hr6	Hr7	Hr8	Hr9	Hr10	Hr11	Hr12	Hr13
13/09/2017							1				1			
14/09/2017		2	4	1	2	1	2							
15/09/2017	4	3	8	3	1	2	6				1			
16/09/2017	4	1	3	2			1				1			
17/09/2017	5	2	15	3		1		3	2	1	5			
18/09/2017	5	6	11	2	1		8	4	2	4	7			
19/09/2017	2	2	3	3	4	1	2	1		2	1			
20/09/2017	1													
21/09/2017		5	10		1	6	5	4	1	2	6			
22/09/2017	1						1							
23/09/2017	8	5	3	1	4	3	3	3	4	4	5	3		
24/09/2017	3	3	5	2	5	7	9	8	6	8	3	5		
25/09/2017	6	4	8	3	6	7	12	7	6	4	3			
26/09/2017	15	6	7	2	6	5	4	5	5	4	1	2		
27/09/2017	1					1		5	5	8	5	2		
28/09/2017	4	6	2	3	1	3	1	3			67	2		
29/09/2017	2	12	14	1			1				2	1		
30/09/2017										1				
01/10/2017								2				1		
02/10/2017	3				1	2	4	5	8	3	1	1		
03/10/2017	5	28	17	9	2	4	2	4	2			1		
04/10/2017														
05/10/2017	2	3	9	2	1	2	1		3					
06/10/2017	2	22	10	12	4	1	1							
07/10/2017	2	5	5		2	3				1	2	3	2	
08/10/2017	5	13	11	3	2	2					2	1		
09/10/2017	1	3	6	2	4	1	1	1		1				
10/10/2017														
11/10/2017														

Phase 3

There is a final flurry of activity at the end of October (Table 3).

Bats recorded during Hr0 must have spent the day in a nearby roost but most of these files were recorded later in the night.

None of the activity before dawn on the morning of 19/10/2017 suggests feeding. All 18 passes occurred between 06:00 and 06:15. Sunrise at 06:39.

Table 3: Phase 3. Number of Nathusius' pipistrelle files recorded each hour after sunset. Hour zero starts at sunset. Daylight hours are highlighted with a pale yellow background.

Files:	Hr0	Hr1	Hr2	Hr3	Hr4	Hr5	Hr6	Hr7	Hr8	Hr9	Hr10	Hr11	Hr12	Hr13
12/10/2017		2	1	1										
13/10/2017	1										1			
14/10/2017	2	2	4											
15/10/2017	2	1	3	1				4						
16/10/2017														
17/10/2017		2												
18/10/2017	2	5	3	1	3								11	7
19/10/2017														
20/10/2017														
21/10/2017														
22/10/2017														
23/10/2017														
24/10/2017														
25/10/2017	6	10	8	3	4	12	3		1					
26/10/2017	4		8	15	2	8	3	5	2	2				
27/10/2017	1			1	3	3	3	2	3					
28/10/2017		2												
29/10/2017	8	10	2	4	2	4	5		1					
30/10/2017	2	1				7	2		1					
31/10/2017		2		1			2	1						
01/11/2017	2			1		1			1		1			
02/11/2017	1	2	1											
03/11/2017	4													
04/11/2017														
05/11/2017														
06/11/2017														
07/11/2017														

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Looking for inspirations?

John J. Kaczanow

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Introduction

These reviews are my interpretations of each book on the readability, informational contents, and most importantly how inspirational and 'mojo' rejuvenating they were, and still are, to me at this time in my batting life (even if some of the information is no longer current). In this article I consider the following books:

1. The White Lady: by Leonard Dubkin
2. British Bats: by Brian Vesey-Fitzgerald
3. The Greater Horseshoe Bat: by Roger Ransome
4. Bats: by Phil Richardson
5. The Secret Lives of Bats: by Merlin Tuttle

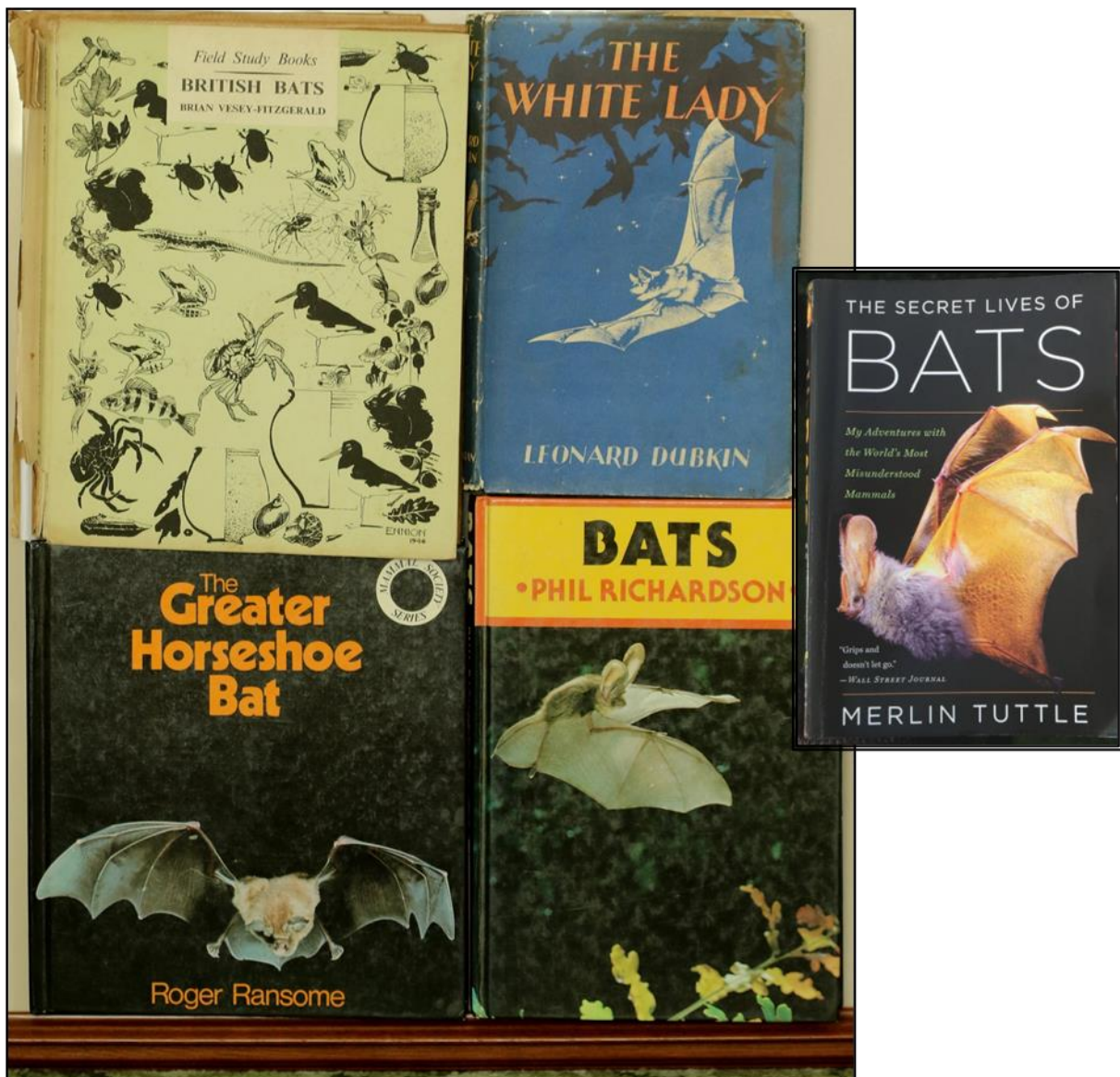


Figure 1: Covers of the five old books reviewed in this article.

The White Lady: by Leonard Dubkin (1900-1972). Macmillan & Co. Ltd, London 1952

Although the species in this volume is not a UK one, the story, and information contained could be about most of our bats. A difficult prologue for me to do; perhaps I should just mirror the original introduction which clearly can't be beaten!

'The White Lady' is the name given by Mr Dubkin, an accomplished American writer and a student of natural history, to a rare albino bat belonging to a colony of little brown bats *Myotis lucifugus* which he discovered by accident on a piece of waste land in Chicago.

He decided to spend as much time as he could in observing these creatures, about which so little seemed to be known. He actually witnessed the birth of the white bat and watched her growing up and learning to fly. His study of the colony taught him many unfamiliar facts about the life and habits of bats, their natural friendliness, and playfulness, their use of a 'radar' system to avoid obstacles in flight, their ability to find their way home at remarkable speed over miles of unknown country, and also raised problems still to be solved.

But there is still an even stranger element in this story of the White Lady, for between her and the author there sprang up an association which seemed to be one of friendship, respect and understanding, despite their totally dissimilar planes of existence. He handled her, fed her, and even took her to his home; she knew and greeted him when he visited the colony. More remarkable still, their relationship brought about his release from a deep inward sense of frustration.

"In the miracle of the White Lady," he tells us, "lay my key to freedom from the prison of my stagnant, defeated self," and the reader will find that his book throws light not only upon some of the secrets of Nature but upon the hidden places of the human heart.

Over-romantic, yes it is to me, but at the same time a really good read and many items of interest, particularly the experiment on the bat's ability to return distant from the roost. My thoughts on this have always, from my early days, been about the animal's ability to navigate by the earth's magnetic field.

The chance of finding such a large accessible roost of any species in my area is rare indeed and finding one would certainly entice me to follow in the author's path.

British Bats: by Brian Vesey-Fitzgerald (1900-1981). Methuen & Co. Ltd, London 1949

I was young indeed when this book was published; being the first British book solely about bats. The author was a long standing respected naturalist, a prolific writer and had numerous books published. As the author said, previously nominal information has been laid down in books about other groups of our fauna which indicates the apparent lack of interest at the time (note the cover illustrations in top left of Figure 1. no bats).

This book has 61 pages of text and illustrations with four full page colour plates. The number of pages illustrates the minimal information about bats at the time; with only 12 species being recorded; although the plan of the series does limit volume size!

Very readable and well laid out, the colour plates are superb. One can, and does say whoops about some pieces of informational text, which can be excused due to the passage of time. On the other hand most information is refreshing and seemingly accurate and questioning.

Page 55 is a must read! Briefly, the author talks of regional variations: Are lesser horseshoe bats *Rhinolophus hipposideros* of western Ireland variable to Hampshire species. Are there more varieties of *Pipistrellus*; he thought there were at least two forms in the British Isles. The author also asked “is it a fact that there are only 12 species in Britain?” and he thought there were more. He also wondered if Bechstein’s bat *Myotis bechsteinii* was as rare as we were led to believe. Remember there is no such thing as absolute rarity. The species must continue or become extinct and he thought there must be a breeding stock!

The Greater Horseshoe Bat: by Roger Ransome. Blandford Press, Dorset 1980

This volume is one of The Mammal Society’s series published to provide Middle School pupils with an authoritative introduction to the wild mammals of Britain.

The author is well acquainted with the subject and produced a most informative and enjoyable read, not only for the target audience but also something for all ages and experience. To have produced such a volume in 43 pages is inspiring. I recommend this book to all that have the slightest interest in bats through to all that have been active for many years. My favourite piece of information is bottom of page 26. A rare and useful piece of information indeed!

The bountiful selection of photo plates and illustrations make a very balanced reading experience.

Bats: by Phil Richardson. Whittet Books, Essex 1985

The authors’ preface is most hilarious, hugely informative and almost a reason alone for buying the book! Copiously filled with superb technical illustrations, and suitable cartoons; along with enormous technical information make for a very pleasurable read.

This book is one that can be taken up for a quick read, reference for facts and figures or just pure enjoyment of the artwork. Hard to find another volume that works as well as this one does!

The Secret Lives of Bats: Merlin Tuttle. Houghton Mifflin Harcourt, Massachusetts 2015

This edition has 288 pages of pure adventurous fact and portrays a man on a mission. That mission is the protection of bats of all species and families. To gain success in his mission Merlin Tuttle had to travel far and wide spending days and weeks seeking out those roosting sites all over the planet. Initially, starting his travels in America and then branching out globally.

To describe his dare devil adventures and the dangers he encountered is way above my epigrammatic intentions when deciding on my very small input to ‘British Islands Bats’. Needless to say his efforts and successes are internationally acknowledged as being at the forefront of bat conservation.

To the up-and-coming bat enthusiast this is not a book to have for species identification, but, unquestionably one to have. Read it with vigour as no doubt you will, and you will be all the better for it.

It is a shame that I did not read this book many years ago; being at an age and time which required something special to give me extra energy in my involvements with Chiropteran species.

It is regretful to say that whilst Merlin Tuttle's past efforts did awaken me, they have not influenced my dealings greatly at this time. Nevertheless, without doubt I do acknowledge his input to the world of bat conservation and sincerely personally thank him for it.

Epilogue

My early inspirations came from bat enthusiasts in the UK who were at the forefront of bat protection and education of such; from whom I gained a huge amount of knowledge and support from those pioneering warriors, namely: John and Win Hooper, Tony Hutson, John Lamerton, Tom McOwat, Dr Roger Ransome, Phil Richardson, and Dr Robert Stebbings.

The books listed above, even in this electronic informational age, have taught me many things, most of all no matter how much knowledge we think we know; there is always more to learn. Let's hope no one will ever know it all, as I believe this is when wildlife will suffer more than it does now!

Lastly but not least: written or computerized information is great to guide us, let's not forget where the real information comes from.....

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Bryanston greater horseshoe bat roost

Colin Morris

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History of Bryanston

Although bats are ‘quite interesting’ having had a 40-year relationship with one building and the bats that live there, I find the history of a site every bit as interesting as the animals themselves.

There was already a 2500-acre estate on the banks of the River Stour above Blandford when the Domesday survey was undertaken in the year 1087. It was owned by a Norman who had previously settled on the Isle of Wight, Bryan de l’Isle, hence his name attaching to the ‘ton’ or settlement - Bryanston. Brian died in 1234, but his birthdate is unknown.

Across the Middle Ages the estate passed through the hands of the ‘de-Stephens’, the ‘Echinghams’ and the ‘de-Boxhalls’ until, in 1415 John Rogers bought it and his descendants remained here for over 250 years. Sir William Berkley-Portman purchased it from the Rogers family in the 1680s and his descendants kept it until 1927 when they lost it through death duties to the state. The Berkley-Portman’s were a renowned family, especially on the Berkley side - there was Danish royal blood in their veins, prior to being Saxon nobility; in 1148 Robert founded the Augustinian monastery at Bristol that is now the cathedral; others fought at Bannockburn, Crécy and Bosworth.

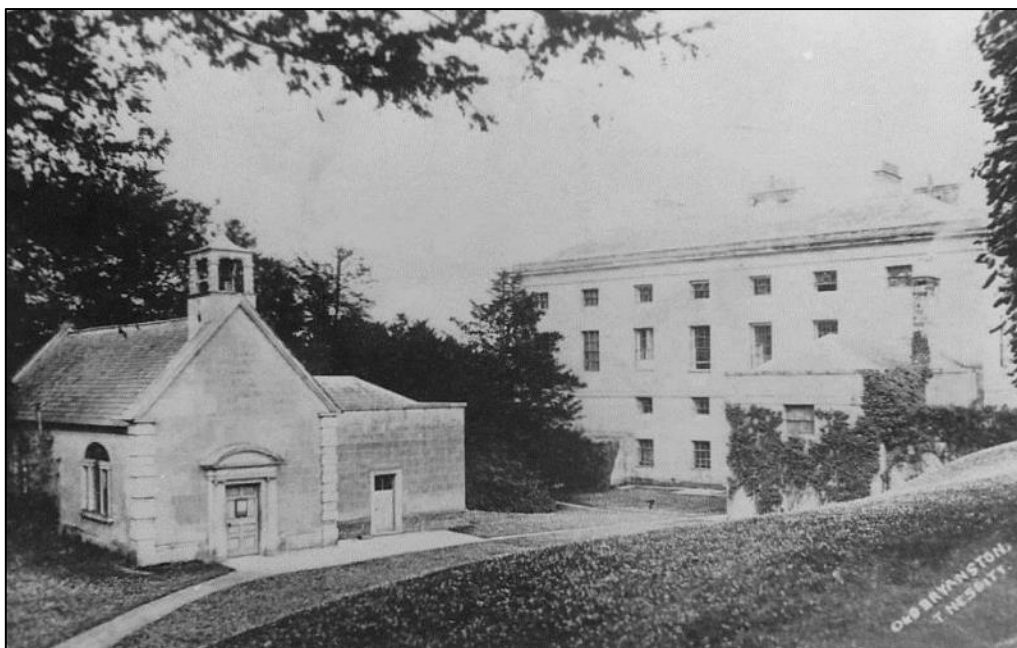


Figure 1: The original Portman residence, built in the 1770s and demolished in the 1890s. In the foreground is the Portman Chapel, which is still in use.

The Portman’s were Somerset gentry with a principal estate at Orchard Portman, near Taunton. The most eminent was the Sir William who became Henry VIII’s Lord Chief Justice. His granddaughter Phillipa married William Berkley, and their grandson, another William, thanks to deaths and a lack of other male heirs, inherited both the Berkley and the Portman estates. Sir William personally captured the usurper Duke of Monmouth in 1685 and soon

after this purchased Bryanston. By the late 18th century, the status conscious family wanted something more stylish and in 1778 employed James Wyatt, the most fashionable architect of the day, to build them a country seat (Figure 1).

The family house sat near the river Stour and was on the site of the present church, St Martins. Photographs of this classical house reveal its elegance but not the discomfort of dampness; even in those days there were ‘cowboy builders’, for the sand they used was ‘sea-sand’ that had not had the salt washed from it. This ‘salty-sand’ drew moisture from the nearby river Stour. Within a few years the dampness had seeped into the foundations and stone walls of the house, making it very uncomfortable for the inhabitants. Labour was cheap in those days and the initial remedy was to change the course of the river, moving it some 80 -100m away; it was too little too late, once dampness is in stonework, it can take many years to dry out, and which is why, after just 110 years the Portman’s were determined to replace it with another mansion some 800m to the north, on higher ground (Figure 2). In 1888 Wyatt’s house was dismantled, and the new house, designed by Norman Shaw, built in a French Renaissance style, was built (Figure 3). Its design has much of the Loire chateau of Ménars about it (Figure 4).



Figure 2: The floods of 2006, showing how close it could come to the house; even after the river had been diverted.



Figure 3: The new house, designed by Norman Shaw, built in a French Renaissance style.



Figure 4: The Loire chateau of Ménars.



Figure 5: The last remaining complete example of Norman Shaw's work; the gatehouse at the Blandford end of the drive.

The present lodge at the Blandford end of the drive is the last complete example of his work on site today (Figure 5). The stone from the dismantled house was not wasted, it was recycled, and St Martins Church (Figure 6) was constructed on part of the original house foundations. Although looking far older than it really is, the church was constructed in 1898 with the dated hopper-heads supporting the construction date (Figure 7). Although, if you look at the arches and sills of the window frames, you'll see they're made from 'new' stone; the original windows were square, so new, arched frames had to be carved.



Figure 6: St Martins Church, built from recycled stone, except for the upper, and lower parts of the window frames.



Figure 7: Hopper heads dated 1898 – The 'P' standing for Portman.

The remaining section of the 1778 house (the 'Old Kitchen Block') has had a variety of uses over the years, during WWII it was used as a billet for American soldiers, in the 1950s it was

Bryanston 'Old Boys Club', and during the late 1960s and early 1970s it was used as a handicraft workshop by the school. The poor condition of the building, and in particular the roof meant it had not been used 'commercially' since then.

The current building (Figure 8), is all that remains of the Portman mansion. The building is approximately 30m long and 9m wide and, as it stands, it is rectangular two-story building with a gable to hip end roof. It is constructed mainly on north-south axis and has a slated roof. It is unusual inasmuch the western elevation is built into the steep chalk hillside. The roof level on this elevation is just 1m above ground level.

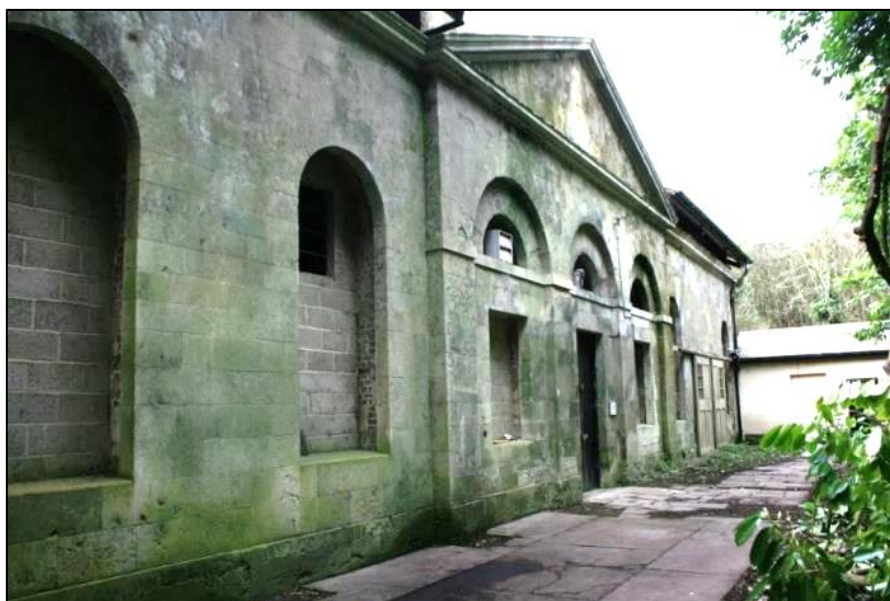


Figure 8: The current building, known as 'the Old Kitchen Block'.

A home for bats

The Grade II listed building is home to a nursery colony of greater horseshoe bats *Rhinolophus ferrumequinum*. The bats breed in the loft. Artificial heating, initially by greenhouse heaters, followed by industrial 'electric blankets', supplements solar heating. In the mid-1990s the electric blankets were replaced by a modern solid-state system that controlled modern greenhouse heaters. During the winter many of the animals stay on site in one of the two artificial caves, these were constructed in 1989 and 1997 respectively. They also roost in other architectural features in the building, including chimneys and an ancillary water tunnel. The Vincent Wildlife Trust purchased the freehold from Bryanston School in 1994.

Other species

A few lesser horseshoe bats *R. hipposideros* have been recorded, both in the summer and winter, and during the winter many other species use the site. Vesper bats have been recorded using door frames, door and window lintels, bat boxes, crevices in brickwork and block-work, and behind cork tiles and timber. These include the common pipistrelle *Pipistrellus pipistrellus*, soprano pipistrelle *P. pygmaeus*, brown long-eared bat *Plecotus auritus*, grey long-eared bat *P. austriacus*, Natterer's bat *Myotis nattereri*, serotine *Eptesicus serotinus*, barbastelle bat *Barbastella barbastellus*, Daubenton's bat *M. daubentonii*, whiskered bat *M. mystacinus*, Brandt's bat *M. brandtii* and Bechstein's bat *M. bechsteinii*.

Bat boxes

Inside the building is hung a range of (damaged) bat boxes, too damaged to use in the field, but perfectly okay to use in a secure site (Figure 9). Rarely used during the summer, they are most often inhabited from October through to March. Here, a grey long-eared bat has chosen to roost behind a Schwegler 1FF (Figure 10). Grey long-eared bats are rare but I frequently recorded them, perhaps one every couple of years.



Figure 9: (left) a serotine using a 2F Schwegler bat box, and (right) a lesser horseshoe bat using a 2FN (but not in a traditional way).

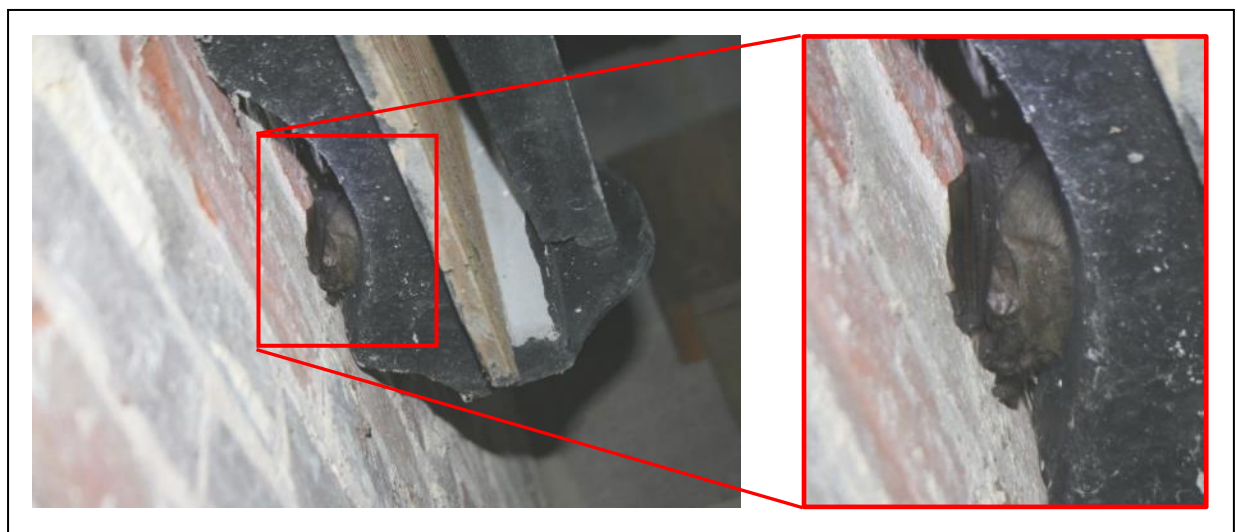


Figure 10: A grey long-eared bat roosting behind a Schwegler 1FF bat box.

The population of greater horseshoe bats in Dorset has been studied since the early 1950s. Michael Blackmore, Andrew Watson, Henry Arnold and Bob Stebbings are just some of the people that have studied here. Andrew Watson (2009, pers. comm.) said he'd seen 'many hundreds' of greater horseshoe bats using a small brick-built building to the south of the main building, but it was too difficult and dangerous to get into the loft. This building no longer exists, and only lower parts of the walls remained when I started visiting to site (Figure 11).

Colin...

...I am delighted to be asked to reminisce about the work that I did studying greater horseshoes at Bryanston, but it will mean digging out ancient records from as far back as the late 1950s.

I think the key to history lies in the fact it was the main nursing colony for the bats that hibernated in the Purbeck mines to the South and at Fonthill to the North. I was introduced to the small loft at the southern end of the building by Michael Blackmore c.1957 who brought a bucket with him and filled it with guano for his garden.

My reminiscences will probably only go as far as 1975 when the bats became protected. There were occasions when I would travel down late in the evening and quietly mount the ladder and lie down under the eaves where I could watch the "bunches" of infants and record the times that the mother bats returned, collected their young and started to feed them. I got some super slides of these babies and just hope they have not deteriorated too much over the past 45 - 50 years!

The destruction of the stone workings in the Purbecks led to the death of huge numbers of bats. A few mines, notably "Normans", were preserved and of course the coastal caves were untouched.

A. Watson. November 2009.

Figure 11: Text from an email received from the late Andrew Watson in 2009 about the bats at Bryanston.

Isn't it strange how you often find out more about a person after they've passed away? Some people are very modest, and Andrew was one such person. At his funeral in 2013 I learnt that he was awarded the George Medal; the highest award for conspicuous gallantry not in the presence of the enemy. I applied for his citation from The National Archives and received the details of how Andrew had earned his medal (Figure 12).

A satellite roost

The Old Kitchen Block was always considered a satellite roost (Figure 13) from the major colony situated above the stables, at Creech Grange (Figure 14) near Corfe. However, this site was effectively destroyed by the spraying of the roof timbers with Lindane (also known as gamma-HCH). Anecdotal reports citing 'several wheel-barrow loads of dead bats being taken away'. Bob Stebbings, after interviewing the gardener some years later, estimated that at least 15,000 bats were killed by this treatment. Many thousands would have died in the year it was applied and many more over the following years as the chemicals used in the treatment would have remained toxic for many years.

THE GEORGE MEDAL

Second-Lieutenant Andrew Page WATSON (129474)
The Lancashire Fusiliers.

On the 28th April, 1941, a Battle aircraft of the Special Duty Flight at Christchurch, fell into the sea some three hundred yards from the shore of Hengisbury, near Christchurch. The pilot of the aircraft attempted to escape by parachute shortly before the aircraft touched the water. The action was noticed by Second-lieutenant Watson, who, at the time was at the top of Hengisbury Head, a steep promontory near Christchurch. He immediately scrambled down the cliffs and swam out to sea, although the currents are notoriously strong and dangerous in this locality, and reached the pilot. He endeavoured to hold the pilot up and to extricate him from his parachute harness in which he was entangled. His efforts, however, were unavailing, and he was compelled ultimately to release his hold through exhaustion. In attempting to regain the shore, Second-lieutenant Watson was himself nearly drowned and was only rescued by a Lance-Corporal and an officer of his own Regiment, who brought him ashore. The sea was bitterly cold and rough. The pilot officer unfortunately died as a result of the accident.

Figure 12: The text of Andrew Watson's citation the George Medal from The National Archives.



Figure 13: Baby greater horseshoe bats in the roof void at Bryanston, from the 1950s. © Andrew Watson.



Figure 14: Creech Grange.

In the late 1970's the original slate roof was in such poor condition it required total refurbishment (Figure 15). In fact, the western elevation had already been replaced with corrugated sheeting, and the lead ridge was constantly leaking (or being stolen). The building was infected by dry rot and, rather than use chemicals that might harm or poison the bats it was decided to remove all the old timber from the site, including the first floor.



Figure 15: The west elevation roof in the 1970s. Corrugated sheets replaced the slates. In the distance you can make out the roof is 'hipped'. This was changed to a gable during the re-roofing.

With financial assistance from the National Heritage Memorial Fund it was partially re-roofed in 1981. The upper floors' ceiling was replaced with a steel and asbestos 'agricultural' style roof (Figure 16). The northern hip-end was changed to a much simpler and cheaper gable design, and only the northern two-thirds of the building re-roofed. The southern end

of the building was left 'open to the skies'. The new southern wall was also converted into a gable. The Portico's roof on the east elevation was also removed to reduce rebuilding costs (Figure 17).

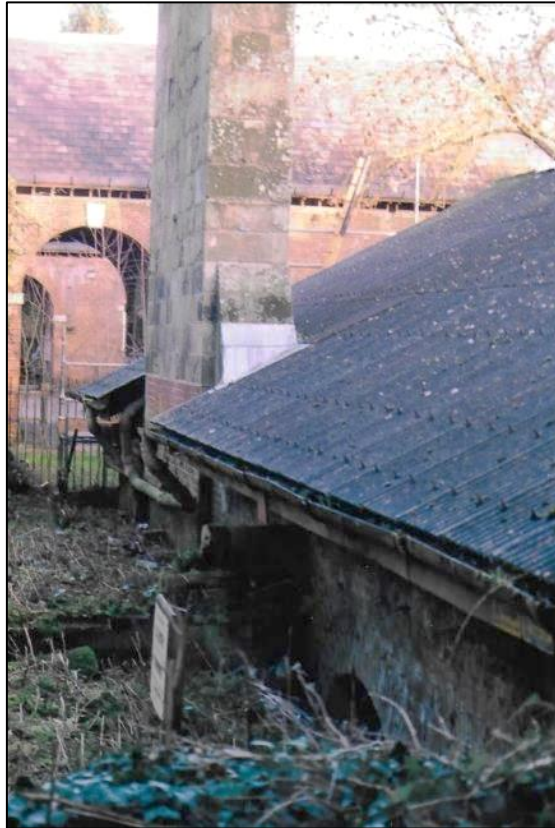


Figure 16: The new roof, white corrugated sheets, fitted in 1981.



Figure 17: The east elevation in the 1970s. The portico was removed to make rebuilding the roof easier (and cheaper).

The white asbestos sheeting had poor heat attraction and retentive properties, even after ‘dousing’ the roof with cow manure and yogurt. The summer following the re-roofing no bats returned to breed, so artificial heating was installed. Consisting initially of several tubular greenhouse heaters that proved ineffective, these were replaced with a bespoke thermal heating pad that resembled an electric blanket and secured to a thick sheet of aluminium to retain heat. To retain more heat, the ‘blanketed area’ was surrounded by cork insulation that created probably the first incubator in the UK.

Andrew’s main study site was the loft of the larger building, that he recorded in his notebook as the bat barn, and he was one of the first people to start the ringing (or banding as it is also know) of bats in the UK, supported by Michael Blackmore (Figure 18). I do remember Andrew telling me of the ‘sack full’ of bats that were taken away from the roost and released, to test their homing ability, most had returned to the roost before he did!

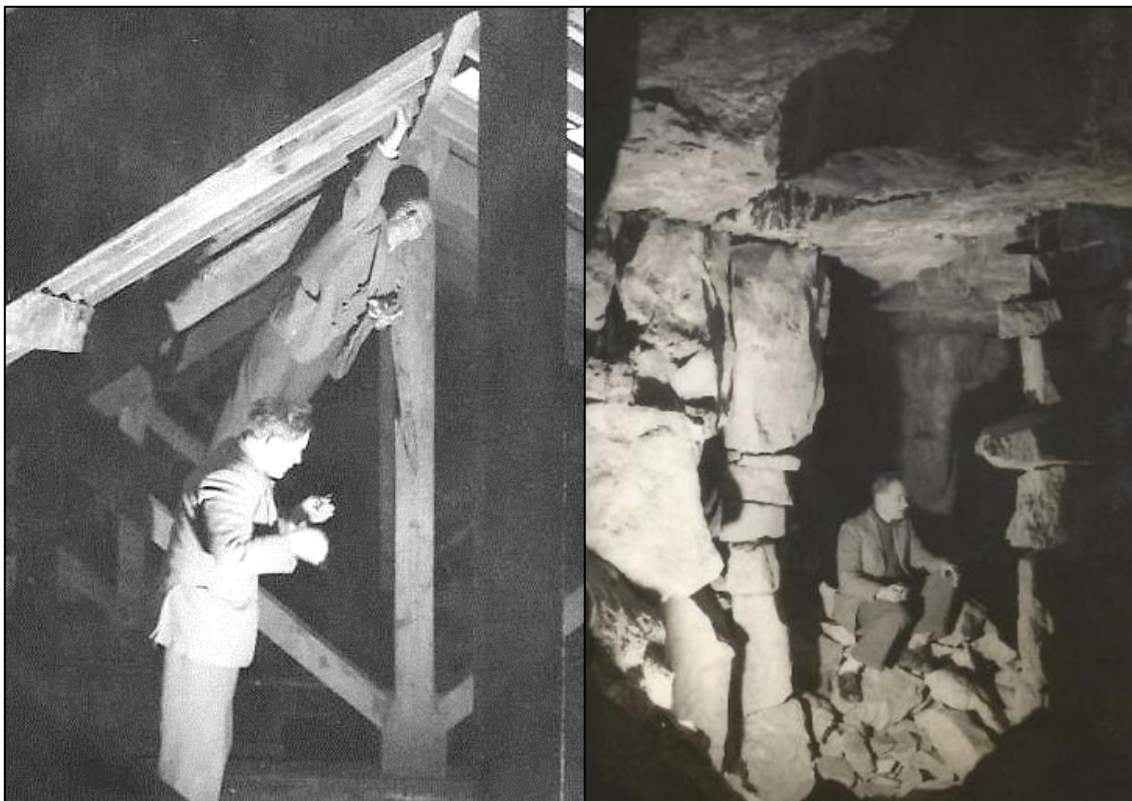


Figure 18: Michael Blackmore handing baby bats down to Andrew Watson (left) and Michael having a bite to eat in a Purbeck quarry, under a cluster of bats (right). Both images were taken sometime in the 1950s.

My involvement

My work with the greater horseshoe bat nursery roost at Bryanston started (unofficially) around forty years ago, in the early 1980s. As an enthusiastic amateur batworker I’d already joined the Dorset Bat Group and was busy surveying houses, usually prior to remedial timber treatment being applied. In those days such work was co-ordinated by the Nature Conservancy Council (NCC) who became English Nature, and eventually Natural England. I started visiting the site with another bat group member, Dave Mockford, and although on private land, we’d sneak into the school grounds, jump over the chestnut paling fence and sit on top of a wide retaining wall to wait for the emerging bats some 6m below us. We

were both delighted in the musical, warbling sounds coming from our ‘new’ bat detector, a ‘QMC mini’ with directional cone – to all intents and purposes it looked like a very cheap plastic radio, with a tin cone that you could clip over the microphone, making it ‘directional’ – oh the sophistication! Things were so much simpler in those days.

On one of these evenings, just before dusk, Dave and I heard a car pull up just below where we were sitting, people talking, and footsteps coming towards us, “We’ve been rumbled”, we thought, and waited for the “just what do you think you’re doing here?”. To our surprise (and delight), it wasn’t a security guard, but Henry Arnold, who, coincidentally was one of our bat licence trainers. Henry had arrived by taxi, to undertake the annual census of babies. The three of us sat quietly for the next hour or so, and counted the bats as they emerged, I think it was around 60 animals (but it was a VERY long time ago), once all the bats had emerged Henry asked if we’d like to come inside to see, count, and measure the baby bats; ‘would we?’ let me think about that for a second...!

Inside it was a bit spooky, all the floors had been removed, which I later found out was because of dry-rot. All that remained were the bare walls and a new loft floor, some 20ft above us. After a climb up the tall, creaking, aluminium ladder, the loft door was opened, and we could hear the baby bats squeaking. The biggest impact was the smell – boy, did it smell! The babies were clustered in a small group, in an incubator warmed by an industrial-grade electric blanket; they got particularly vocal when we shone our torches on them and they started to jiggle about and crawl around.

Henry placed a step-ladder under them, climbed up, and gently unhooked a baby from the ceiling timber and examined it. In his notebook he recorded its sex, weighed it, and measured its forearm. He took out a pair of scissors and cut off the bats first toe-nail (making it bat number one). I wasn’t aware of why he needed to mark the babies, but it became clear a bit later. Henry handed me the baby bat – my first time in a greater horseshoe bat roost and I was handling a baby greater horseshoe bat, talk about ‘cool’. On the second bat, Henry collected the same biometric data, then cut off the second toe-nail; on the third bat, the third toe-nail, and so on. It was when we reached the 11th bat I was wondering what Henry would do? No problem, it was toe-nails one and two, followed by toe-nails one and three, one and four, and so-on. Thankfully, in those days there weren’t too many babies (I think it was around twenty-five in total), so no baby had more than two toe-nails cut off.

After about an hour we had completed the work, just as the first mum returned to find and feed her baby. It was then the reason for marking each bat became clear. Henry was revisiting the site in two weeks’ time and, by marking the bats, he could record how each bat had grown in the intervening period, as well as answer questions like; does cold weather slow growth, or warm weather increase it? It’s all clear now, but even in those days some aspects of bat ecology were still unknown. This was the start of my long association with the site.

In the late 1970s , the traditional wood and slate roof was removed and replaced with a modern steel-framed, and asbestos sheet roof. Straight away, a problem with internal temperatures meant the bats failed to breed. To overcome this, artificial heating, in the

form of greenhouse heaters were installed, and the following year, bespoke industrial electric blankets were fitted and breeding resumed (Figure 19).



Figure 19: A cluster of baby bats (2017).

Although the site was first notified as a Site of Special Scientific Interest (SSSI) as a *breeding* roost in 1977, small numbers of bats regularly hibernated there in secluded parts of the building. However, most of the animals left the building and flew many miles to find more suitable places to hibernate. Many bats flew south (and still do) to the stone quarries in Purbeck, and occasionally animals flew across to the Isle of Wight. Some bats flew north to other industrial excavations near Chilmark, Wiltshire and Bath, North Somerset. One intrepid individual flew west to Beer, in south Devon. Collecting this information was made possible by the bat ringing carried out by Andrew Watson and Michael Blackmore.

The World's first...

Despite it being quite a large building, Bryanston didn't supply a range of temperatures that encouraged many bats to overwinter here. I think the most we recorded was around 18 animals, which roosted mainly in the large chimney flues and an old water tunnel.

In 1988, to encourage more bats to overwinter Bob Stebbings suggested we excavate....'the world's first artificial cave in solid rock for hibernating bats'. Because the building was built into a chalk hillside, the west elevation was essentially around 4m underground, it had the potential for us to dig into it. The plan was to excavate a 'T-shaped' tunnel, with the main tunnel sloping downwards at about 25° and the 'cross-section' at the top twisted, with one arm going downwards about 2m, to retain a pocket of cold air, and the other arm going upwards around 3m, to trap a pocket of warm air (Figure 20).

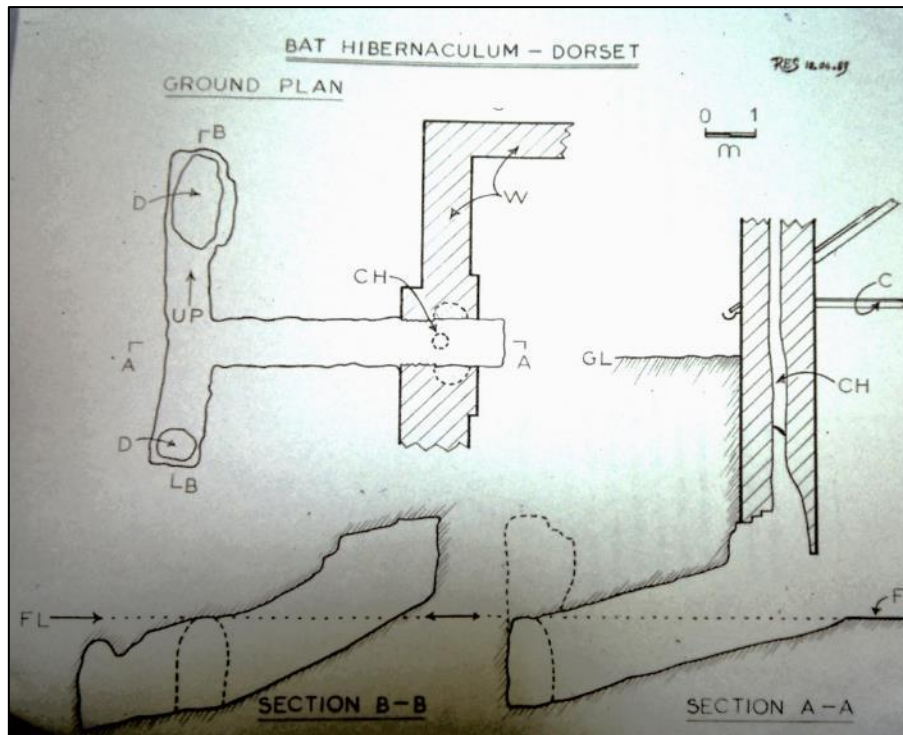


Figure 20: Plans for the artificial bat hibernaculum at Bryanston.

So, early in 1989 we started the project. One Friday evening, at 18:00 we began by removing the bricks from the back of a fireplace (Figure 21), exposing the raw chalk-face and, using an electric jackhammer, pick-hammers, and hand picks started excavating; we worked until midnight, by this time, we'd gone in about 2m (Figure 22).



Figure 21: One Friday night in 1989, removing bricks from the back of the fireplace. Dave Mockford, Pat Cashman, Bob Stebbings and Maurice Webber.



Figure 22: By the end of the Friday evening, we'd gone in around 2m.

On the Saturday morning, we started at 06:00 and, to our surprise and delight (sort of...) a greater horseshoe bat was already roosting in the cave. I say 'sort of' because we had to disturb it, and Bob moved it to a quieter part of the building, where it could go back into torpor and we could continue digging. I'd arranged for a team of volunteers, mostly from the Dorset Bat Group, but also English Nature to arrive, in four-hour shifts throughout the day. We worked, until 22:00 and by this time had excavated the 'main tunnel' and started one of the 'branches'. Excavated rubble was put into a box-on-wheels (Figure 23), affectionately called 'the pig' (which was adorned with the appropriate decoration).



Figure 23. The box on wheels, affectionately known as 'the pig', used to pull out the rubble.

The following day we started at 06:00, and a continuous team of volunteers from the Dorset Bat Group, working in four-hour shifts, continued until 22:00. The following day we had a 'lie-in' and started digging around 08:00, by 13:00 we had completed the tunnel. Over just one weekend, under the direction of Dr Robert Stebbings and Maurice Webber, volunteers

from the Dorset Bat Group excavated a 11m 'T-shaped' tunnel - removing over 40 tonnes of chalk (Figures 24 and 25).



Figure 24: Excavated spoil, before...



Figure 25: ...and after, approximately 40 tonnes of chalk.

A few years later the tunnel was extended (internally) using concrete blocks and polystyrene (Figure 26). From just a handful of individuals hibernating in the building in the 1980s, by 2018 there were over 300 bats.

Since I started visiting the site, there has been a steady rise in the number of bats returning and breeding; from around sixty adults in the early 1980s, to over 300 adults in 2020. Some of the recent increase might be attributed to bats that have joined this site from a nearby roost that has had some building works undertaken (author's own unpublished data).



Figure 26: Cave extension (internal) using concrete blocks and polystyrene.

In 1999, on the south-west corner of the site, a second, much larger tunnel was excavated by a team of former tin miners from Cornwall. A new slate roof was installed to stop ongoing damage to walls on the part of the building without a roof (Figure 27).



Figure 27: (left) a second, much bigger tunnel was excavated in 1999, by a team of former tin miners from Cornwall, and (right) the final section of roof, on the south elevation.

My long association with the site continues, as I still occasionally visit 'my old friend', when invited by Daniel Hargreaves, from The Vincent Wildlife Trust.

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Has COVID-19 impacted on the public perception of bats in the UK and what are the implications for their conservation?

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Introduction

The emergence of SARS-CoV-2 (the virus that causes COVID-19) had a huge impact globally on human health and the economy. From the start of the pandemic to the time of writing (2021) there had been 166,346,635 confirmed cases and 3,449,117 deaths (WHO, 2021), and in 2020 the global economy shrunk by an estimated 4.4% triggering a global recession and pushing an estimated 90 million extra people into extreme poverty (IMF, 2020). Research into the origin of the virus became a priority in the hopes that a greater understanding would help to better prepare for potential future emerging viruses and prevent a repetition of such wide ranging and devastating consequences (WHO, 2015).

There were many theories as to the source of the virus, but bats were suspects from early on, potentially with transmission through an intermediate host (Lu *et al.*, 2020; Shereen *et al.*, 2020; Zhou *et al.*, 2020). At the time the most current research surmised that *Rhinolophus* species were the most likely source (Boni *et al.*, 2020; Latinne *et al.*, 2020; Wacharapluesadee *et al.*, 2021) with the discovery of a coronavirus, RaTG13, with 96% genetic similarity to SARS-CoV-2 in an intermediate horseshoe bat *Rhinolophus affinis* bat (Zhou *et al.*, 2020). Boni *et al.* (2020) estimated that RaTG13 and SARS-CoV-2 diverged between 40-70 years ago stating that this demonstrated high levels of co-infection within *Rhinolophus* species. They suggested that, due to the level of recombination events in this viral reservoir, SARS-CoV-2 may not even have required an intermediate to evolve and become zoonotic.

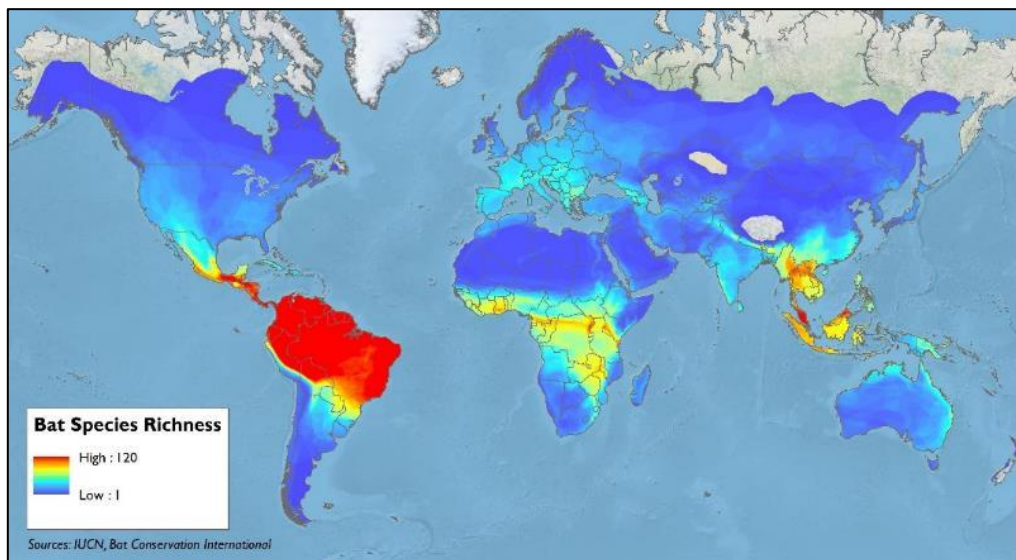


Figure 1: An illustration of the abundance of bat species worldwide.

Bats are known to host many viruses without displaying symptoms such as Nipah, lyssaviruses, Hendra and coronaviruses (Bonilla-Aldana *et al.*, 2021), and have been suggested as hosting more viruses than any other species (Olival *et al.*, 2017). However, Mollentze and Streicker (2020) found that viral capacity and zoonoses frequency are linked

to species richness. As bats are a diverse order of mammals with 21 families worldwide consisting of >1400 species (Figure 1), accounting for almost a quarter of all mammal species (Wilson and Mittermeier, 2019), it may just appear that they host more viruses.

Viral spillover events are facilitated by human-induced changes that lead to increased contact between wildlife and human activity, where the probability of viral transmission and mutation is increased (Daszak *et al.*, 2006; Jones *et al.*, 2012; Quammen, 2012). This has been demonstrated in previous viral emergences: SARS-CoV in 2003 (Quammen, 2012; Andiman, 2018), and Middle East Respiratory Syndrome (MERS) in 2012 (Farak *et al.*, 2018), where wildlife presence overlapped with human activity, which it is thought led to viral transmission from bats to intermediary hosts; civets (Luk *et al.*, 2019) and dromedary camels (Farak *et al.*, 2018; WHO, 2019) respectively (Figure 2). These human-induced changes occur for a variety of reasons; deforestation for commercial and agricultural expansion, urbanisation and intensification, land-use change and management practices (Patz *et al.*, 2004; Foley *et al.*, 2005); which can all result in habitat loss and fragmentation (Patz *et al.*, 2004). Many of these changes are known to cause stress among bat populations (Seltmann *et al.*, 2017) which Plowright *et al.* (2008) found increased the risk of bat-borne virus transmission.

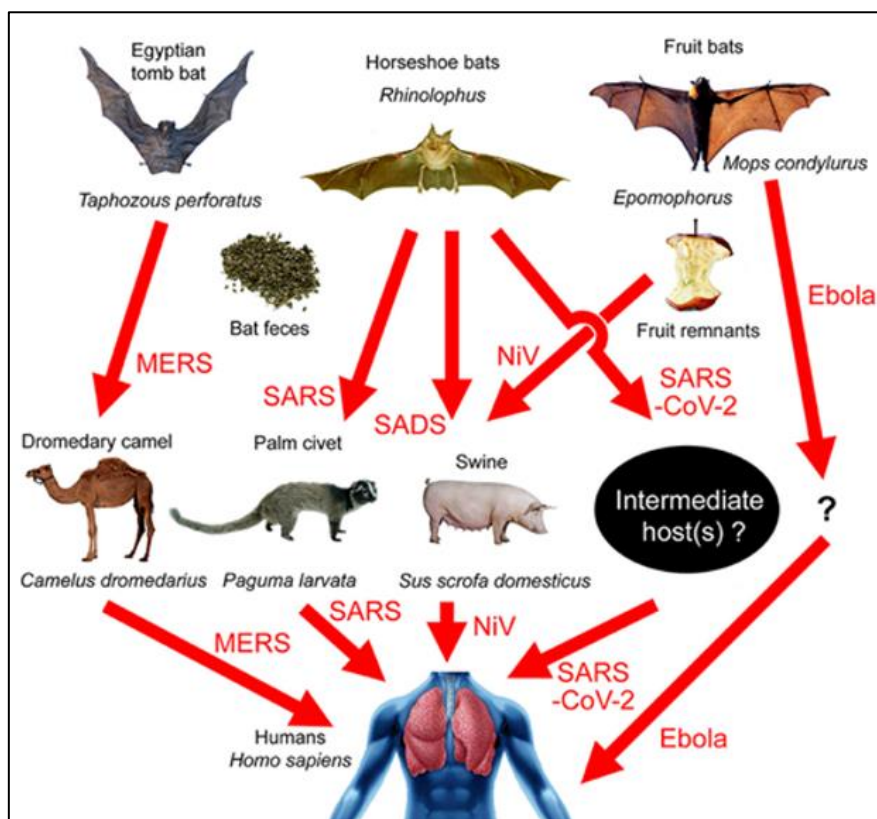


Figure 2: Viral spillover from bats to humans through intermediate hosts (Yuan *et al.*, 2020).

These human-induced changes directly threaten biodiversity. Bat populations are vulnerable, with 80% of species assessed by the IUCN as requiring research or conservation attention (Frick *et al.*, 2020), largely due to anthropogenic threats. Conflict with human interests can lead to persecution; for example, fruit farmers cull bats to prevent commercial fruit predation, but they are often operating under misconceptions regarding the predation

contribution of bats (Del Vaglio *et al.*, 2011; Aziz *et al.*, 2016) ignoring predation by other species such as birds (Raharimihaj *et al.*, 2016; Oleksy *et al.*, 2018). Also unregulated hunting of bats for bushmeat affects around 167 species and has led to the extirpation of at least four species (Mildenstein *et al.*, 2016).

Attitudes towards bats can have a huge impact on their survival, with them often viewed as a nuisance in buildings (Voigt *et al.*, 2015). People also tend to have negative attitudes towards species they fear (Batt, 2009), which typically includes bats as they are traditionally associated with evil (Hill and Smith, 1984; Musila *et al.*, 2018). Lack of knowledge has been shown to impact on attitudes (Hoffmaster *et al.*, 2016; Lim and Wilson, 2019; Lu *et al.*, 2021) and knowledge of the ecological and economic importance of bats is often lacking (Tanalgo *et al.*, 2016). Bats global ecological and economic contribution is well demonstrated, helping to drive healthy ecosystems and provide direct benefits to humans (Taylor, 2019).

Insectivorous bats can eat up to two thirds of their body mass in insects per day reducing the need for chemical pesticides, benefiting other wildlife (Ghanem and Voigt, 2012) and saving agriculture vast sums on pest control (Boyles *et al.*, 2011; Ghanem and Voigt, 2012; Kolkert *et al.*, 2021). They also help control the spread of insect-borne diseases such as malaria (Taylor, 2019; Puig-Montserrat *et al.*, 2020). Bat guano is a valuable fertiliser (Ghanem and Voigt, 2012; Taylor, 2019). Fruit and nectar eating bats are responsible for the seed dispersal and pollination of more than 500 plant species, including economically valuable plants like figs, mangoes, bananas, durian, and agave, contributing to forest regeneration, plant maintenance and food provision for other species including humans (Ghanem and Voigt, 2012; Taylor, 2019). The diversity and ecology of bats also provides huge potential for research: for example, in disease defence (Jebb *et al.*, 2020), cancer prevention (Koh *et al.*, 2019), blood clotting disorders and strokes (Taylor, 2019), and sonar and radar advancement (Ma and Muller, 2011; Taylor, 2019).



Figure 3: Pest control, seed dispersal and pollination performed by bats. © Merlin Tuttle.

Public attitudes towards an issue or subject can be influenced inordinately by media coverage, providing incorrect or incomplete information, and directing attention towards specific points (McCombs, 2008). Extensive and misleading media coverage of the hypothesised link between bats and SARS-CoV-2 led to a significant increase in public interest in the negative association between bats and coronavirus (Cerri *et al.*, 2020). Cerri *et al.* (2020) found that after media coverage of the first victim of SARS-CoV-2, searches on Google relating to bats and coronaviruses increased significantly. Misinterpretation of scientific evidence by the media (Ridley, 2020) negatively affects public attitudes towards an issue of which they have limited knowledge (McCombs, 2008) (Figure 4).

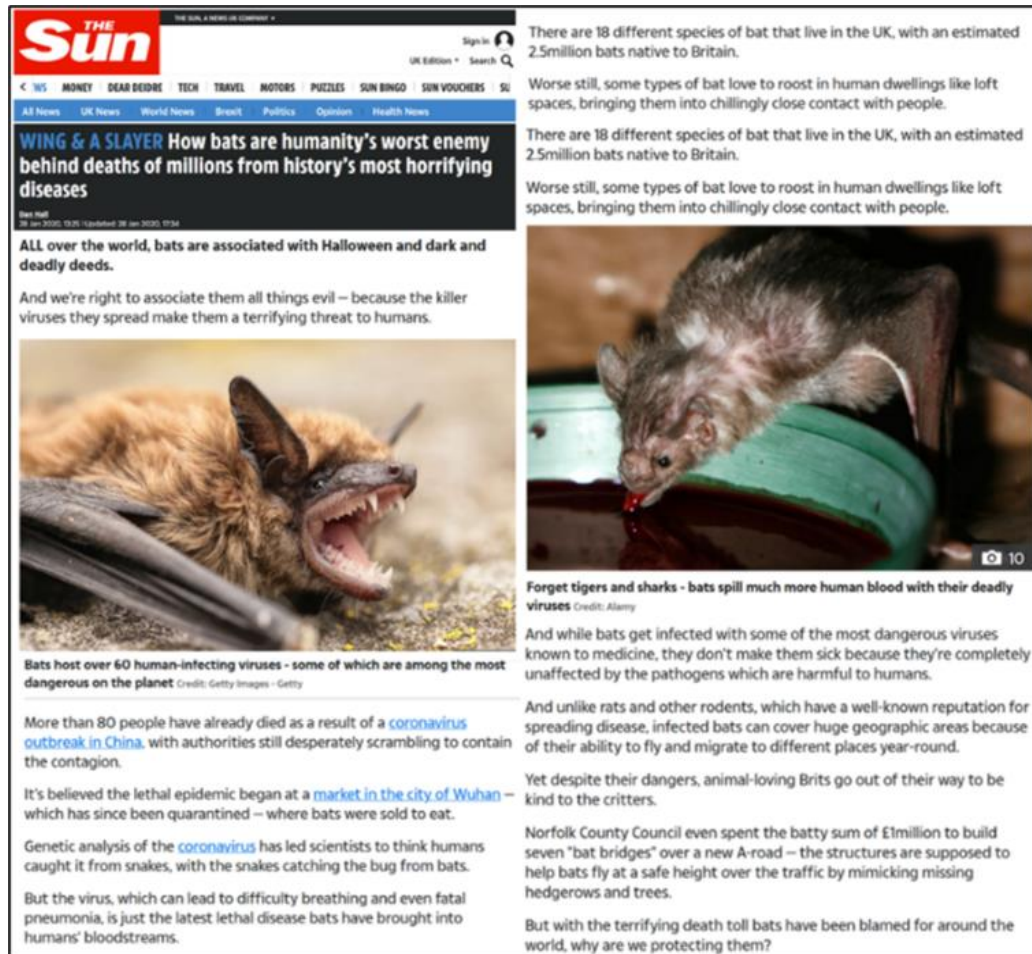


Figure 4: Example of a media story within the UK at the beginning of the pandemic.

The rapid spread of misinformation is facilitated by social media outlets where messages can be further distorted (MacFarlane and Rocha, 2020) (Figure 5), so bats as the potential source of SARS-CoV-2 is reframed as 'Bats spread COVID-19' (López-Baucells, Rocha and Fernández-Llamazares, 2018). Focus on the negative traits of bats without knowledge or consideration of their positive ecological roles drives negative public attitudes which can have devastating repercussions (MacFarlane and Rocha, 2020; Zhao, 2020; Lu *et al.*, 2021).



Figure 5: Examples of social media posts during the SARS-CoV-2 pandemic (Twitter, 2020).

These repercussions pose a huge threat to global bat populations (López-Baucells *et al.*, 2018; MacFarlane and Rocha, 2020; Zhao, 2020), overshadowing their ecological value and compromising conservation efforts (López-Baucells *et al.*, 2018). The extent of potential repercussions was demonstrated by reports of culling events in the name of COVID-19 prevention. In Peru locals planned to set fire to a roost of mouse-eared bats before the authorities intervened (PhysOrg, 2020, Gómez Durán, 2020), 200 fruit bats were massacred in India before government intervention (Goyal, 2020), in Indonesia authorities killed hundreds of fruit bats at a market (Tsang, 2020) (Figure 6), and enquiries from the public about removing or culling bats near homes occurred in China and India (Deshpande, 2020). Culling has been proven an ineffective method of controlling viral spread (Hallam and Mccracken, 2011; Streicker *et al.*, 2012) as it increases stress on bats, suppressing their immune system and thereby inducing an increase in the spread of bat-borne viruses (Amman *et al.*, 2014; Plowright *et al.*, 2015; Olival, 2016).

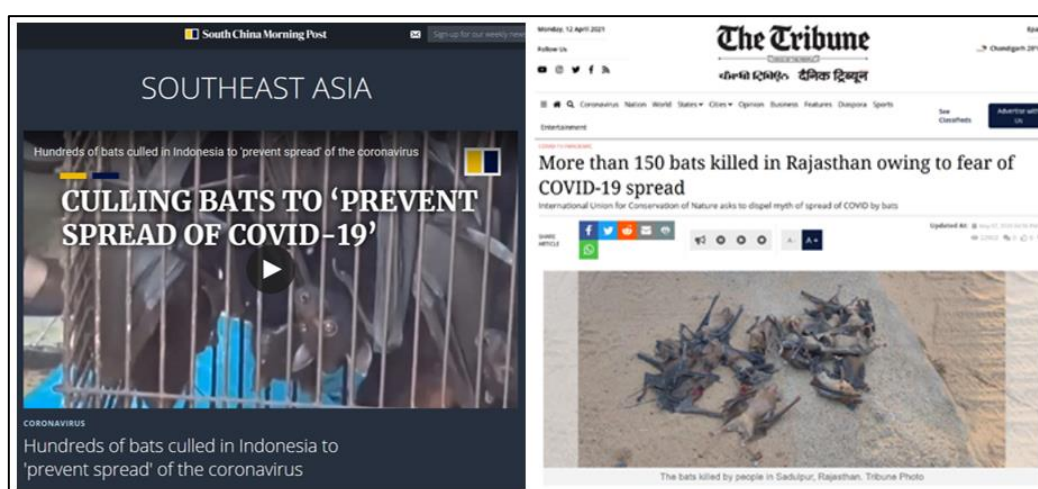


Figure 6: News reports of culling events as a COVID-19 spread prevention measure.

To counteract the misinformation and prevent further persecution of bats various conservation organisations released statements (CMS, 2020) and created campaigns such as #DontBlameBats (SECEMU, 2020). Lack of knowledge and understanding fosters negative attitudes (Barnes, 2013; Hassan *et al.*, 2020), but improving knowledge through educational programs has proven significant in improving attitudes and behaviour towards bats (Mahmood-ul-Hassan *et al.*, 2011; Hoffmaster *et al.*, 2016; Musila *et al.*, 2018; Lu *et al.*, 2021). The positive influence of knowledge of bats ecological importance is demonstrated in a village in Odisha where, despite some fruit predation and the negativity surrounding SARS-CoV-2, the locals have protected and fed them for years (Times of India, 2013; Senapati, 2020), allowing the population to increase from around 150 to over 1000 (Times of India, 2013).

This study aimed to assess the affect that SARS-CoV-2 had on the public perception of bats in the UK. Although coronaviruses distantly related to SARS-CoV have been found in UK bats, none are zoonotic (Adams, 2012). Assessing the public's knowledge of this, if they consider UK bats a risk of transmission, and their level of knowledge of the global ecological contributions of bats could help direct educational efforts. Conservation efforts over the decades have successfully addressed peoples' negative perceptions of bats and ignorance of their importance to ecosystem health (Ebua *et al.*, 2011; Racey, 2013; Hoffmaster *et al.*,

2016; Lu *et al.*, 2021). Misinformation and misleading negative media coverage can magnify the perceptions of risk at the expense of the progress made through these efforts (López-Baucells *et al.*, 2018). Assessing the public perception of bats and whether the pandemic had an affect could provide an insight into the potential impacts on the conservation of bat populations within the UK.

Method

Two questionnaires were created. The first was aimed at the general public to obtain a broad perspective of public opinion throughout the UK, to evaluate their perception and knowledge of UK bats, their level of risk regarding coronavirus transmission and the ecosystem services performed by bats globally. The second was aimed at individuals and organisations in the UK who encounter both the public and bats: wildlife rescue, ecologists, bat-related organisations (e.g. Bat Conservation Trust), regional diocese (as bats roost in churches), wildlife conservation groups (e.g. regional Wildlife Trusts), and environmental organisations (e.g. Natural England).

To reach a broad spectrum of the target group the public questionnaire was distributed online via approximately 40 selected regional groups on social media. These groups were created specifically to share advice and information regarding the SARS-CoV-2 pandemic. The bat worker questionnaire was also distributed online via a combination of targeted social media groups, but also via email to relevant organisations.

Results and Discussion

The results of this study demonstrated that the public had a predominantly high opinion of bats before the pandemic (Figure 7) and that, despite the tide of misinformation and negative framings by the media in the early stages, only a minority of opinion was negatively affected with 95% claiming no effect at all.

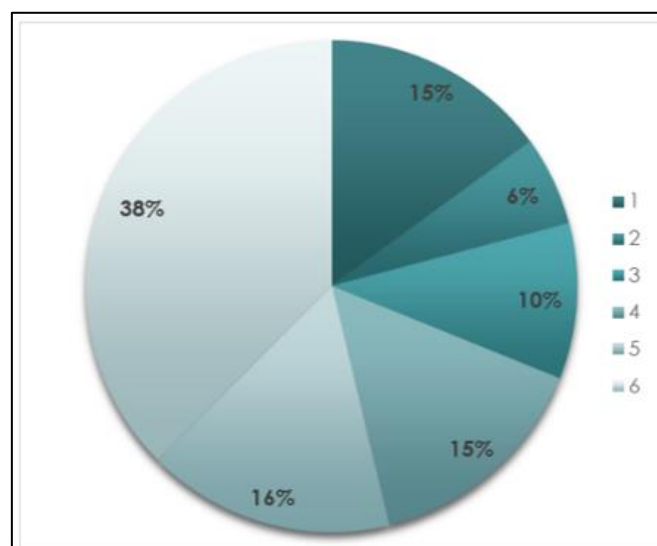


Figure 7: Distribution of the opinion of bats where 1=lowest and 6=highest opinion.

Focus on the negative attributes of bats without knowledge of their positive ecological contributions can foster negative attitudes towards them (MacFarlane and Rocha, 2020; Lu *et al.*, 2021). Mahmood-ul-Hassan *et al.* (2011) found that 100% of respondents in their

study were unaware of the ecological services performed by bats which was reflected in the negative attitude towards them. However, knowledge of the important ecological role of bats within this study was high (Figure 8) which could account for the low impact of the pandemic on the level of opinion.

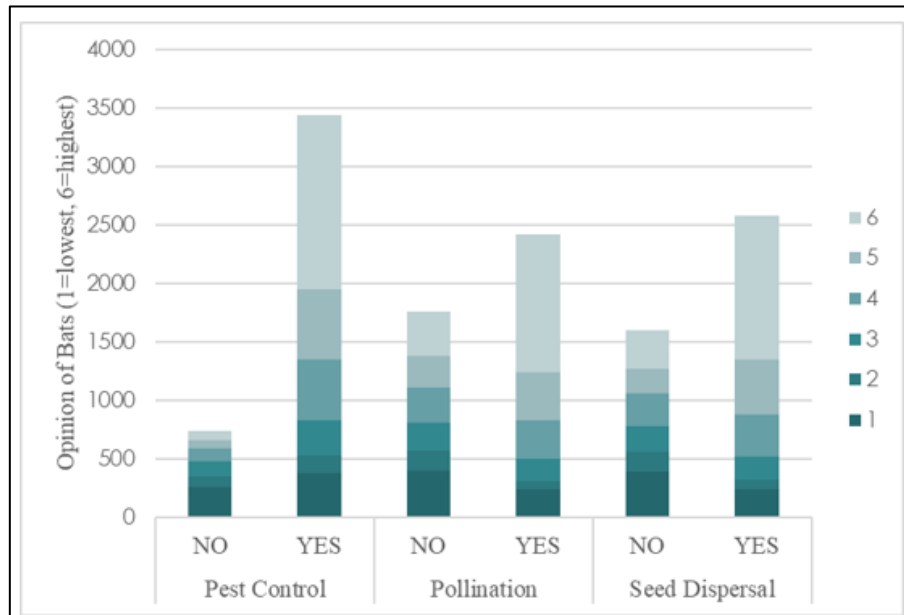


Figure 8: Association between knowledge of the various ecosystem services performed by bats and level of opinion.

Occupations that encounter both the public and bats in some capacity generally experience a certain level of negativity targeted at bats, dependent on the nature of their interaction with the public. For example, protection for bats in the UK has been incorporated into planning legislation, so building developments require bat surveys and possibly mitigation to be undertaken (Bat Conservation Trust, undated^a). Ecologists employed to conduct these surveys can face negativity from people resentful of the extent and cost of the requirements (Birks *et al.*, 2012). However, 73% of respondents in the bat workers questionnaire stated that they had not experienced an increase in negativity through the pandemic and 91% had not received any enquiries relating to bats and SARS-CoV-2, despite the potential concern regarding bats roosting in buildings occupied or frequented by people. These results dispute the findings of MacFarlane and Rocha (2020) that public attitudes and perceptions suffer long term negative impacts because of media misinformation.

Among those in the public survey whose opinion was affected, the direction of the change was the opposite of what was expected, with a significant shift towards improved opinion (Figure 9). This result is contrary to the findings of Lu *et al.* (2021) that showed an almost 15% increase in negative attitudes after the start of the pandemic.

England – South West

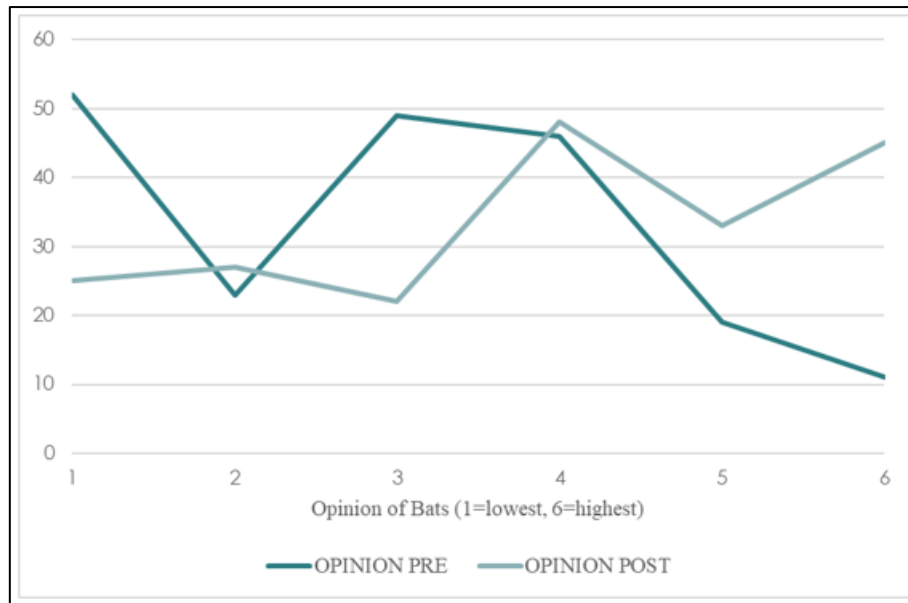


Figure 9: Change in level of opinion from pre pandemic to post pandemic for those whose opinion was affected.

The media exert immense influence on public attention and can focus that attention on specific facets of an issue (McCombs, 2008). Misinformation and exaggeration of negative traits can undoubtedly have disastrous consequences (MacFarlane and Rocha, 2020; Atehortua and Patino, 2021), which in the case of SARS-CoV-2 led to the persecution and slaughter of bats across the globe (Deshpande, 2020; Gómez Durán, 2020; Goyal, 2020; Tsang, 2020; PhysOrg, 2020). However, the increase in internet searches related to bats experienced during the pandemic (Cerri *et al.*, 2020) could potentially account for the increased opinion of bats amongst the respondents who stated that the pandemic had an effect, as they could have discovered accurate information relating not only to bats association with coronaviruses, but also in relation to their diversity, and ecological and economic benefits. This suggests areas for further research to discover the reasons for the positive change in opinion.

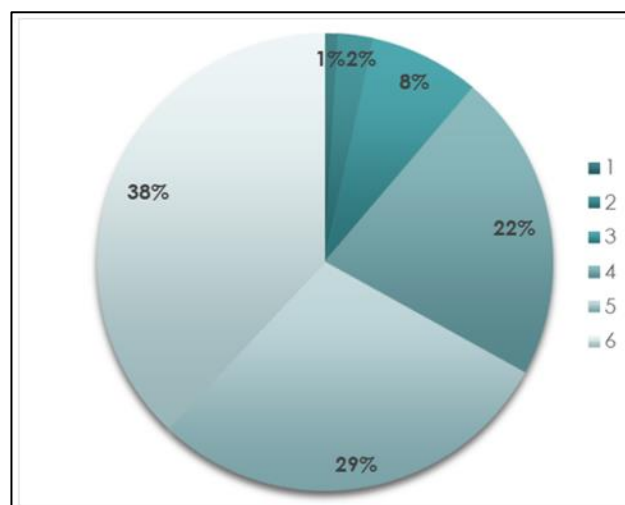


Figure 10: level of interest in nature and wildlife where 1=lowest and 6=highest level of interest.

This positive change amongst those whose opinion was affected could also be linked to the significantly high level of interest in nature and wildlife observed among the sample (Figure 10), with the focus on bats again prompting research and positive outcomes in the form of increased opinion.

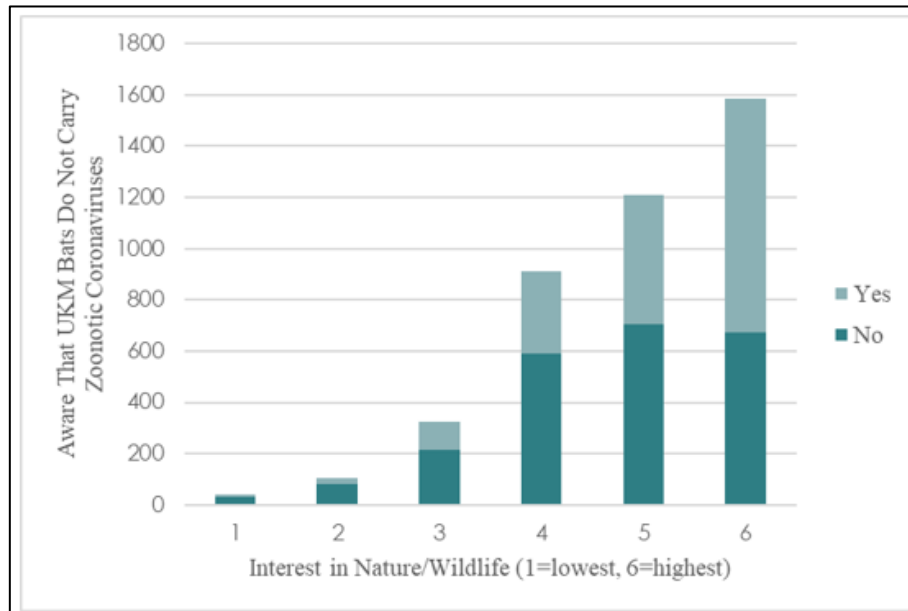


Figure 11: Association between level of interest in nature and wildlife and knowledge that UK bats do not carry zoonotic coronaviruses.

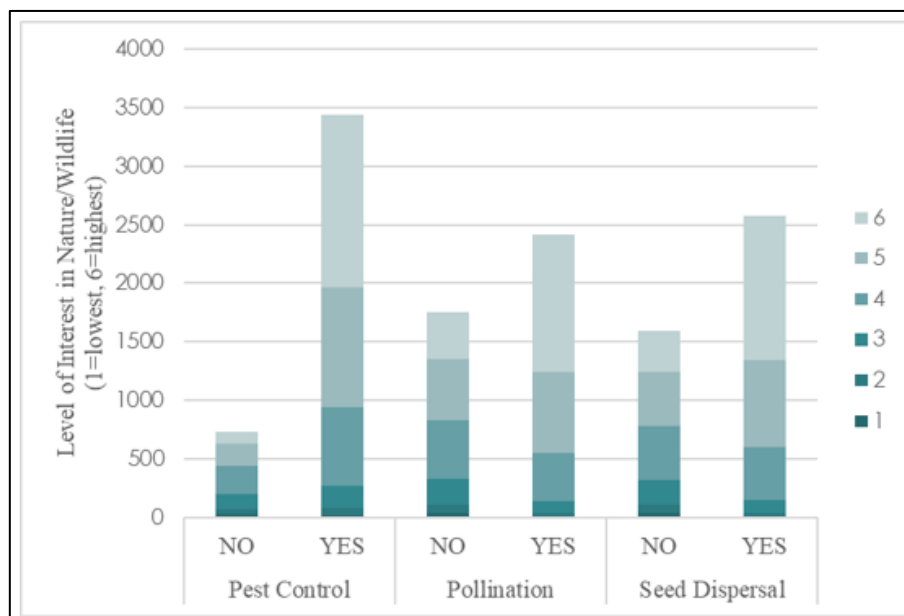


Figure 12: Association between level of interest in nature and wildlife and knowledge of ecosystem services performed by bats.

Although coronaviruses have been found in UK bats, none are zoonotic (Adams, 2012) and globally bats play a significant ecological and economic role (Taylor, 2019). The high level of interest in nature and wildlife amongst respondents in this study positively associated with the results for all the questions evaluating knowledge relating to these facts (Figures 11 and

12), demonstrating that a higher interest in the natural world leads to greater knowledge in relation to it.

There was also a positive association between knowledge and the level of opinion of bats, with those having the highest opinion demonstrating the greatest awareness of the lack of zoonotic coronaviruses in UK bats and the global ecological services performed by bat species (Figures 8 and 13).

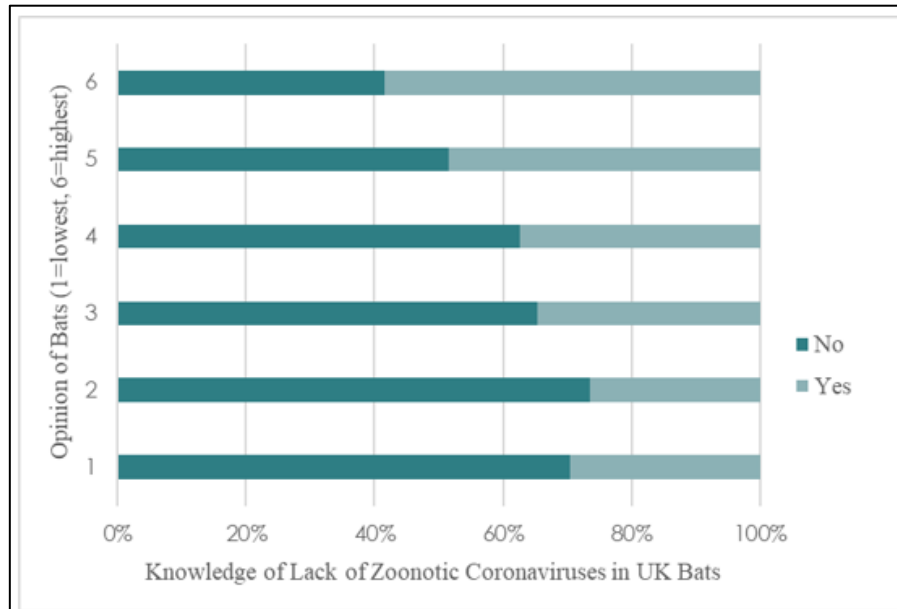


Figure 13: The association between knowledge of the lack of zoonotic coronaviruses in UK bats and level of opinion of bats.

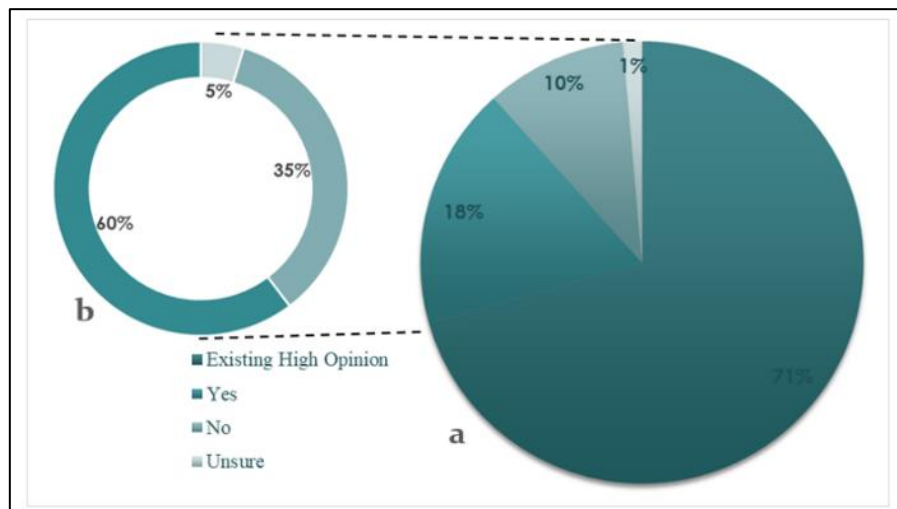


Figure 14: The effect of learning of bats ecosystem services on the opinion of the whole sample (a), and for those that did not have a pre-existing high opinion of bats (b).

In their study in Malaysia, Lim and Wilson (2019) found that over 50% of respondents had a positive attitude towards bat conservation, which corresponded with knowledge of the role of bats in the pollination of economically valuable fruit trees. Similarly, Lu *et al.* (2021) found that conservation education highlighting the diversity and ecological value of bats and the

threats they face raised public attitudes towards bats by almost 10%. In this survey 60% of those who did not have a pre-existing high opinion of bats admitted that learning of bats ecosystems services improved their opinion of bats (Figure 14). Some of the comments received in relation to this point are detailed in the table in Appendix A.

The lack of zoonotic coronaviruses in UK bats means they are not a risk in the transmission of SARS-CoV-2 to humans, but a significant number of respondents were unaware of this. Those unaware that UK bats do not carry zoonotic coronaviruses were more likely to consider them a risk in the transmission of SARS-CoV-2 (Figure 15).

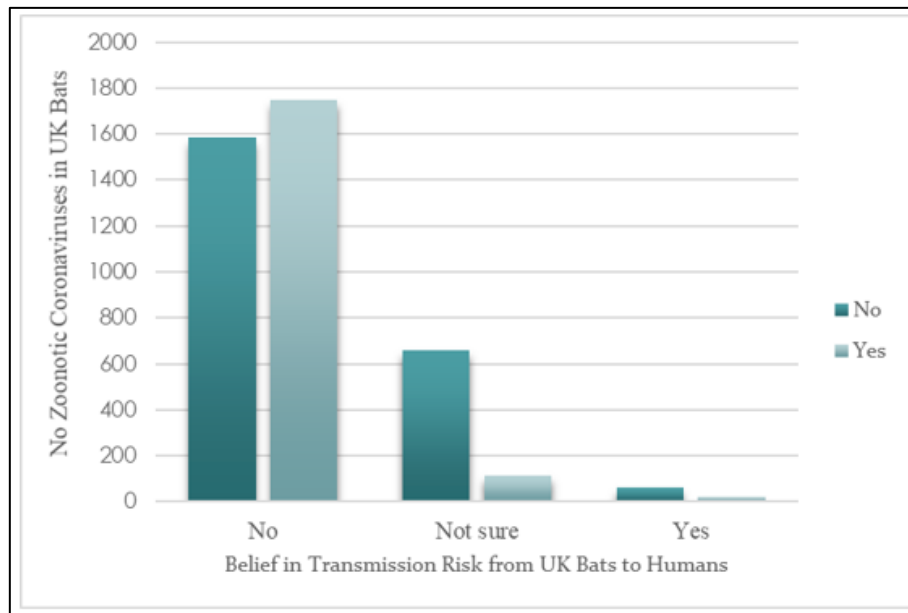


Figure 15: Association between knowledge of the lack of zoonotic coronaviruses in UK bats and belief they are a transmission risk of SARS-CoV-2 to humans.

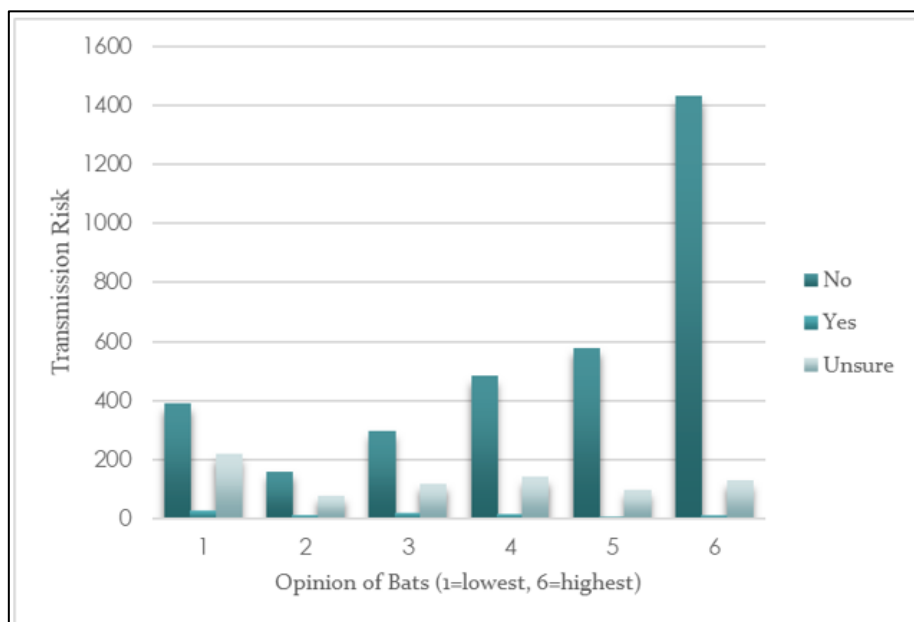


Figure 16: Association between opinion of bats and the belief they are a transmission risk of SARS-CoV-2 to humans.

There was also a significant association between the level of opinion of bats and belief in the transmission risk, with those having the lowest opinion exhibiting the greatest uncertainty of the risks (Figure 16). These findings support those of Lu *et al.* (2021) where nearly 85% of respondents misunderstood the relationship between bats and SARS-CoV-2, with over 50% believing that bats were highly likely to be a risk in transmission to humans, thereby strengthening negative attitudes towards bats.

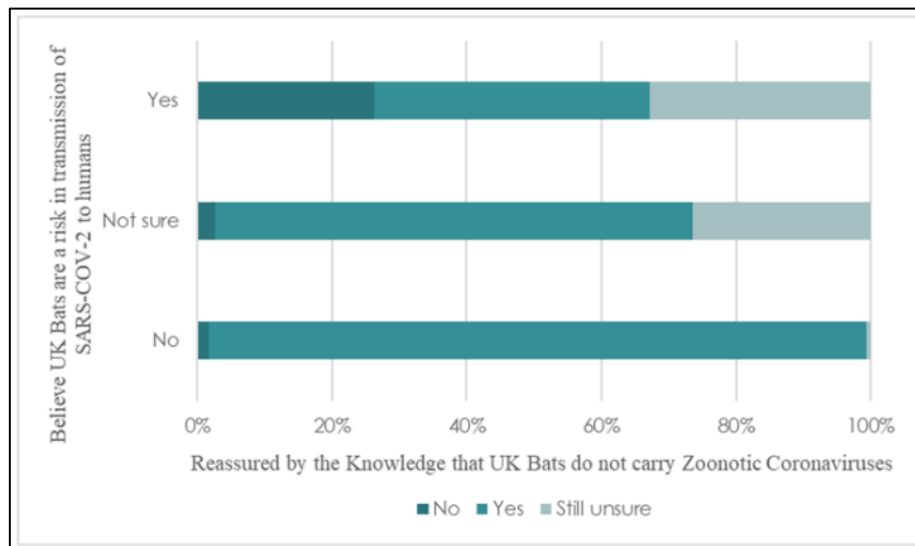


Figure 17: Association between belief in UK bats as a transmission risk of SARS-CoV-2 to humans and feeling reassured regarding the risk after learning that UK bats do not carry zoonotic coronaviruses.

However, when respondents in this study were asked if the knowledge that UK bats do not host zoonotic coronaviruses provided reassurance regarding the transmission risk the result was contradictory. Despite 92% stating they were reassured further tests showed that these were people already aware of the lack of risk, those who thought UK bats might be a risk or exhibited uncertainty were either not reassured or remained uncertain (Figure 17). This further agrees with the study by Lu *et al.* (2021) where, even after educational measures clarifying the bat-virus relationship, nearly 60% of participants still believed that bats were a direct risk of transmission of SARS-CoV-2 to humans. MacFarlane and Rocha (2020) suggest that this could be the result of the ‘continued influence of misinformation’, a phenomenon whereby associations are strengthened through repetition. Consequently, repeating the misinformation regarding the association between bats and SARS-CoV-2, even to refute it, could worsen the issue.

Age proved to be a significant factor in many aspects of the study, there were significant associations with levels of interest in nature and overall opinion of bats, with the older age groups (51+) scoring higher for both (Figures 18 and 19). Older generations often exhibit a higher degree of connection to the natural world (Dean *et al.*, 2018). Musila *et al.* (2018) suggested that negative attitudes can diminish over time and exposure to the natural world resulting in better appreciation in later years. Jones *et al.* (2020) found that older generations were more aware of environmental changes than young people, citing the example that younger age groups were less mindful of the declining abundance and

biodiversity of local bird species. This generational amnesia, where knowledge is imperceptibly lost between generations, can hinder conservation efforts (Jones *et al.*, 2020).

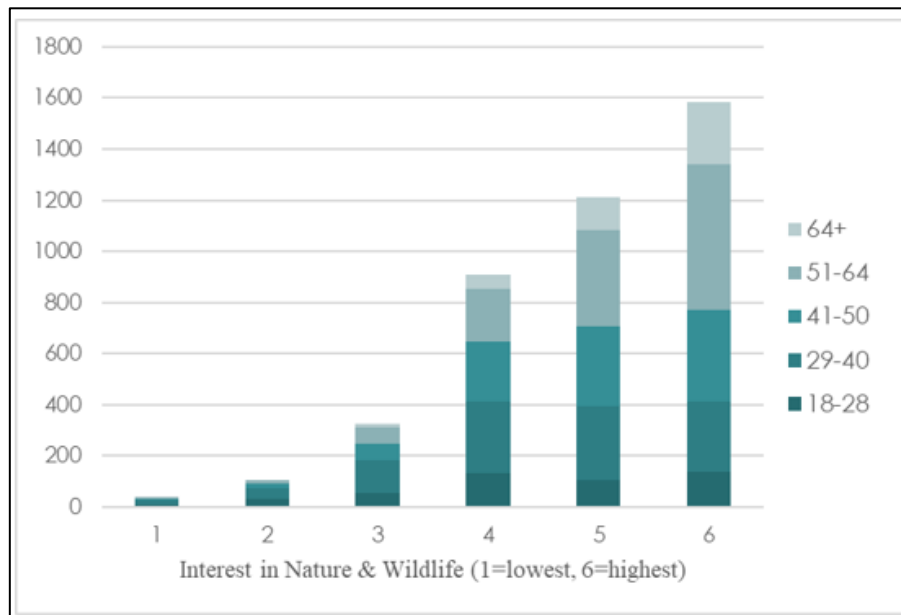


Figure 18: Association between age group and level of interest in nature and wildlife.

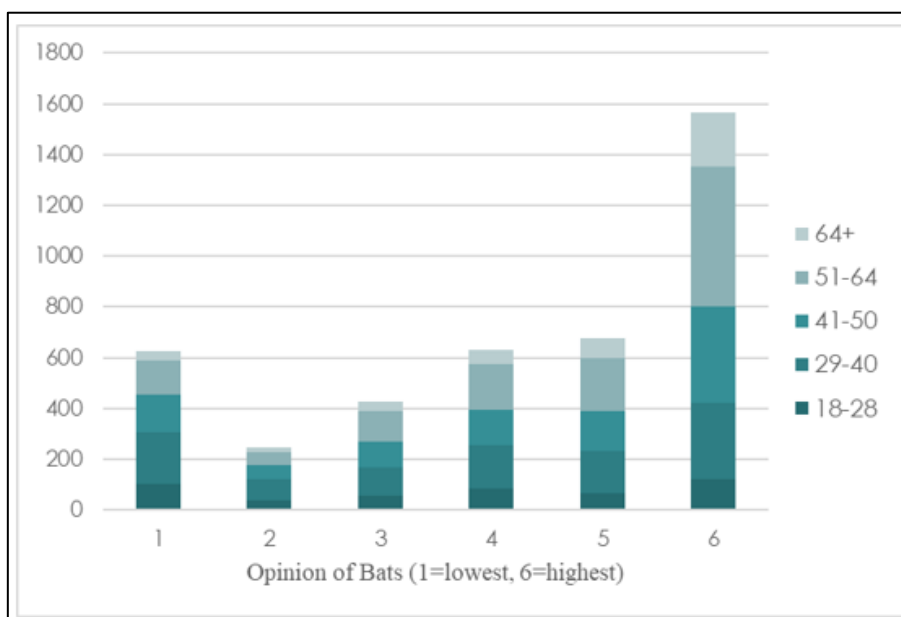


Figure 19: Association between age group and opinion of bats.

The significance of age within this study was further demonstrated with the highest level of interest in nature and wildlife amongst retired respondents. Increased interest in the natural world in retirement is often due to the increase in spare time. Research into the demographics of British wildlife tourists found that the majority were retired professionals over 55 years of age, with many also volunteering regularly with local wildlife organisations, often contributing their professional skills for the organisations benefit (Curtin, 2008). It has been well established that experiencing the natural world positively impacts our general health and wellbeing (Dean *et al.*, 2018; Bratman *et al.*, 2019; White *et al.*, 2019). Even

simple nature-related activities can increase our connection with nature (Richardson *et al.*, 2020), indeed Orr *et al.* (2016) found that simply enjoying a ‘green’ view from a window had a positive impact on the mood and wellbeing of older people within a care home setting.

Engaging with nature, even in simple ways, is key in the development of positive attitudes and pro-environmental behaviours (Cosquer, Raymond and Prevot-Julliard, 2012; Rosa and Collado, 2019; Richardson *et al.*, 2020). Most respondents in this study had encountered bats in some way, predominantly this was simply observing them flying around, and the association demonstrated between these encounters and a higher opinion of bats supports this concept (Figure 20).

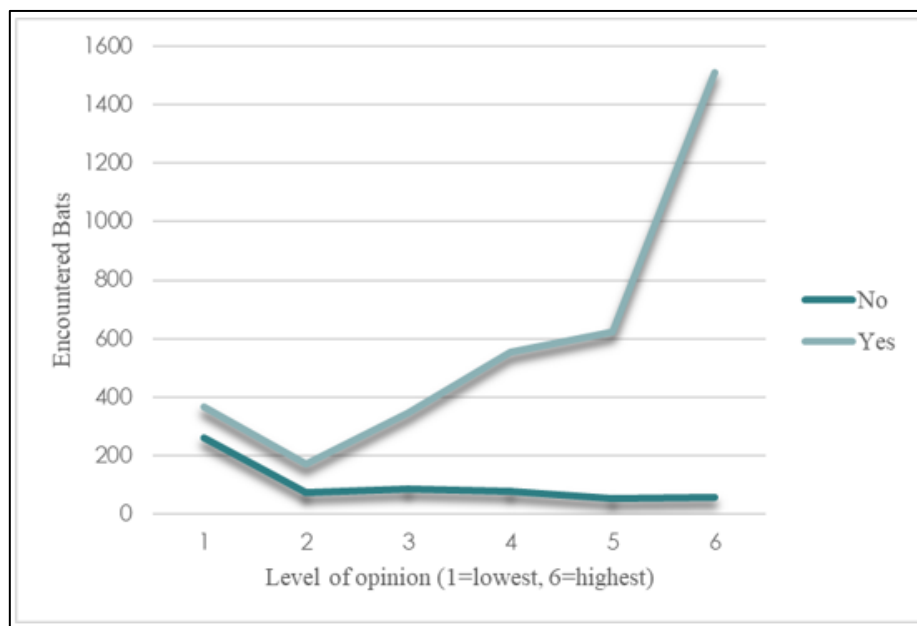


Figure 20: Association between encountering bats in some way and level of opinion of bats.

The negative effects of the pandemic lockdown measures on mental health and wellbeing were considerable (Banks and Xu, 2020; Niedzwiedz *et al.*, 2020), however one of the ways people found to cope was to interact with nature (Pouso *et al.*, 2021). Multiple sources reported that there was a large increase in people wanting to spend time in nature (Lemmey, 2020; Office for National Statistics, 2021). A National Trust poll (2020) found that over two-thirds of adults said that spending time in nature made them feel happy, indicating an increase in nature connectedness. There were reports that 2020 was the busiest year for wildlife hospitals with significant increases in the number of animals brought in for treatment, with bats among the species brought in (Salter, 2020). Among the animal rescue sector in this study there were no significant results, responses regarding the numbers of bats brought in for care since the start of the pandemic were equally distributed between increase, decrease and no difference. Among those that had seen an increase, most did believe it was due to the pandemic (Figure 21), specifically due to the increased amount of time spent at home increasing the likelihood of people finding injured bats. However, the very small sample makes it difficult to draw any significant conclusions.

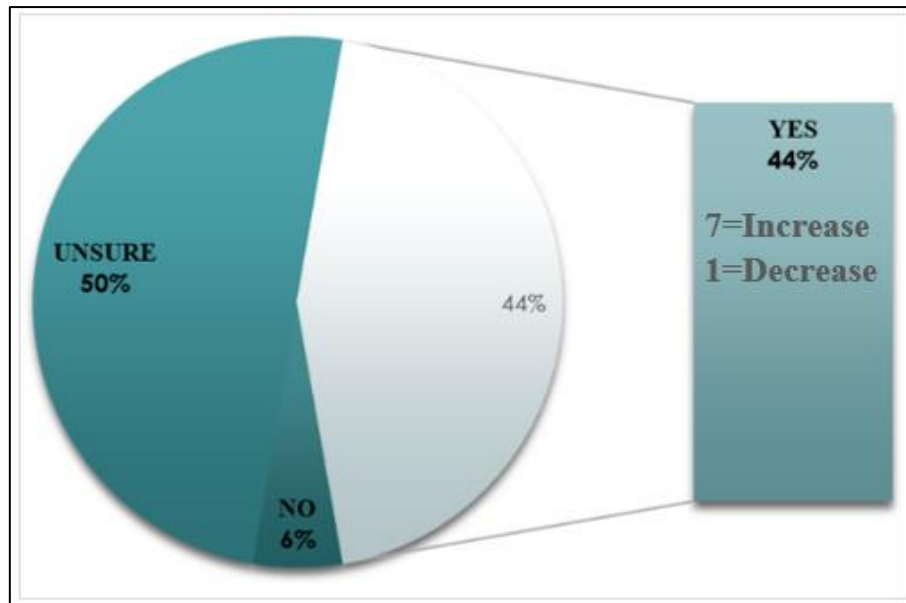


Figure 21: Bat rescues that saw a difference in numbers brought into care and cited the pandemic as the reason.

The bat worker sample was not equally distributed, a significant majority of respondents were ecologists, which was expected as it was easier to reach a greater number through social media groups. There were difficulties locating relevant contacts within organisations to access the required information for the survey, and time constraints limited the potential for success. The sample for the animal rescue sector was very small with only 32 respondents, which is a fraction of the bat rescue provision in the UK. The Bat Conservation Trust's UK Bat Care Network has 218 bat carers, 47 ambulance drivers, 14 regional helplines and nine wildlife hospitals registered. Each of the regional helplines and hospitals have numerous bat carers engaged and there will be many more bat carers that are not registered with BCT (Worledge, 2021, pers. comm.). Further research could specifically target individual sectors, for example, focus on the animal rescue sector could potentially establish if there was a significant difference in numbers of bats brought into care through the pandemic and the relative attitudes of members of the public.

In addition to people spending more time in nature through the pandemic, the inclination to learn about nature also increased. Webpages for wildlife charities reported increased traffic, visits to the RSPB website rose by 69% with nearly 80% of those visits from new users (Office for National Statistics, 2021) and Lemmey (2021) found that over a third of those participating in their study intentionally engaged with media to research nature, for example to identify species. This demonstrates an interest and willingness to learn about wildlife and nature indicating education potential in relation to bats, as increasing knowledge about biodiversity can cultivate pro-environmental attitudes and behaviour (Cosquer *et al.*, 2012). Previous studies have linked higher levels of education with increased pro-environmental attitudes and behaviours (Meyer, 2015; Hoffmann and Muttarak, 2020) and the results in this study seem to reflect these findings. Those having achieved postgraduate level of education had a higher opinion of bats than those with lower education levels (Figure 22).

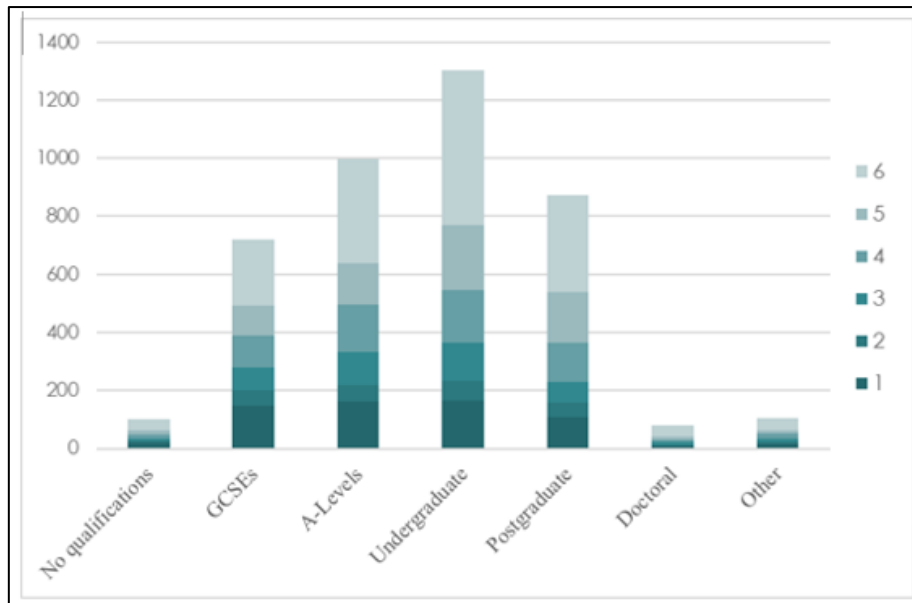


Figure 22: Association between education level and opinion of bats.

Knowledge levels of bat related facts in this study also appear to be influenced by education level, with an association between lack of knowledge of pollination and seed dispersal services performed by bats and GCSE level, and knowledge of the lack of zoonotic coronaviruses in UK bats and doctoral degree level.

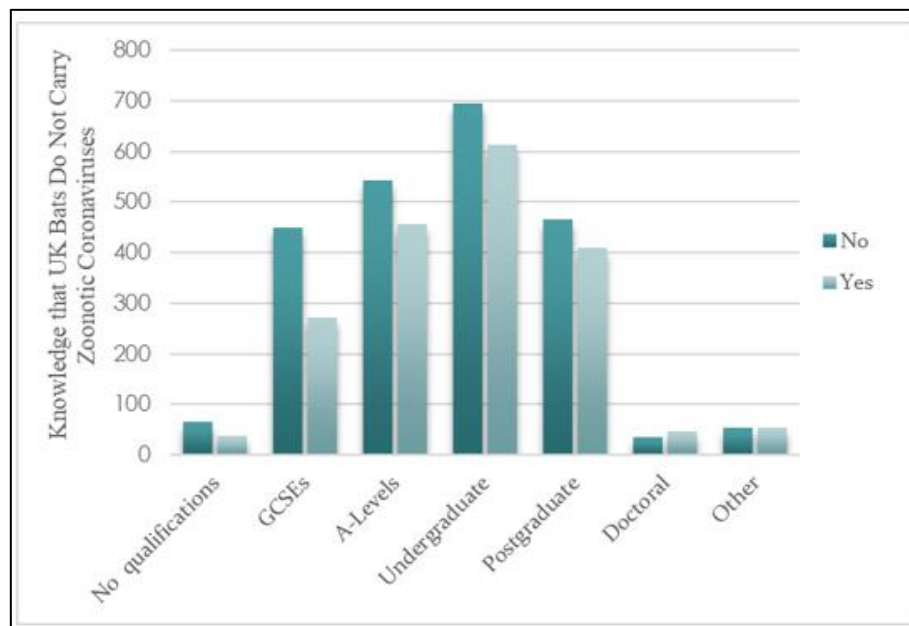


Figure 23: Association between education level and knowledge that UK bats do not carry zoonotic coronaviruses.

There was no association between knowledge of pest control services and education level, which was surprising as all UK bats are insectivorous (Figures 23 and 24). However, there was a more significant association between the level of interest in nature and wildlife and knowledge among the sample group in this study, greater interest equaled greater knowledge (Figure 12). This suggests that the content of the education is more important for specific issues, whereas general environmental education is maybe linked to greater

environmental awareness rather than promoting attitudes towards individual species. Ardoin *et al.* (2020) suggest that although environmental education can be effective, the outcome can depend on the topic, meaning that more generalised topics will have indirect outcomes, whereas more focused programs will have direct results. This was reflected in the findings of Lu *et al.* (2021) where the direct educational method proved more effective than the more indirect method in influencing attitudes.

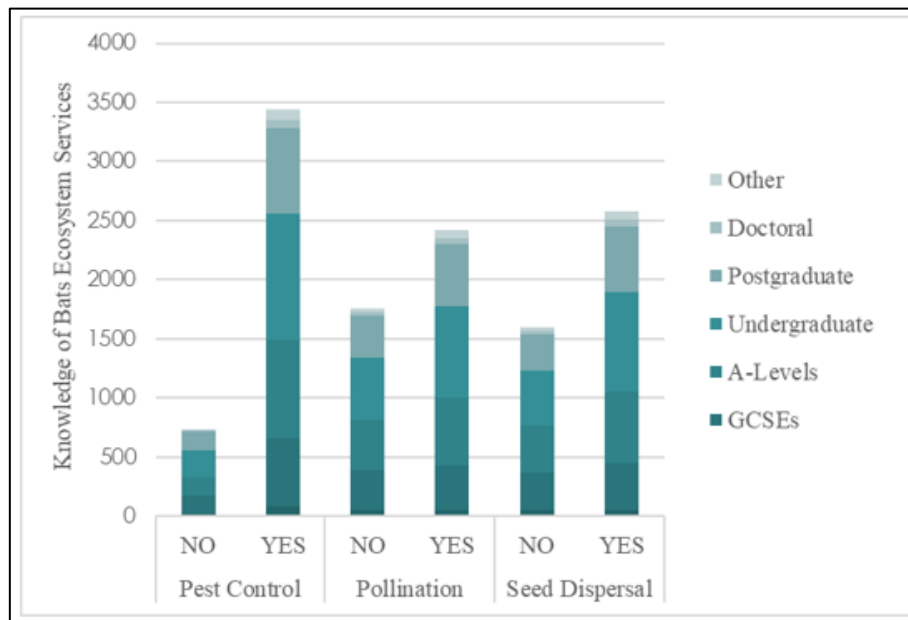


Figure 24: Association between education level and knowledge of the ecosystem services performed by bats.

Although levels of enquiries and negativity received within the bat worker survey were not significant, the comments that were received by the relatively small sample provide a hint of the attitudes that exist within the public and business sectors in the UK (see table in Appendix B). Reports by Deshpande (2020) of an increase in sentiment for removal of roosts from within the vicinity of populated areas in China and India in the wake of the SARS-CoV-2 outbreak were reflected within this study, with a number of comments conveying concern relating to the perceived health risks of bats within buildings occupied or frequented by humans. The level of education behind the enquiries is unknown, with the exception of a comment referring to misinformation instigated by a professor warning of the transmission of SARS-CoV-2 from bat guano, so no conclusions can be drawn regarding their relative level of environmental awareness. However, the success of conservation education is well known and is fundamental in the promotion of bat conservation (Racey, 2013; Fagan *et al.*, 2018). Targeted educational measures positively impact on attitudes and appreciation of the value of bats and increase the likelihood of actively supporting bat management strategies (Mahmood-ul-Hassan *et al.*, 2011; Racey, 2013; Hoffmaster *et al.*, 2016; Fagan *et al.*, 2018; Lu *et al.*, 2021). For example, Lim and Wilson (2019) found that those aware of the importance of bat pollination services in fruit production were more likely to support measures to protect bats.

Amongst the enquiries received by bat workers within this study were several from contractors regarding the perceived risks of working within a building occupied by bats,

indicating a gap in knowledge relating to the transmission risk of SARS-CoV-2 to humans from bats in the UK. This suggests a potential need for targeted educational measures within this sector. Training opportunities relating to bats within various sectors, including construction, already exist (Bat Conservation Trust, undated^b), however individuals need to be aware of their lack of knowledge (Welburn *et al.*, 2015) and willing to act on it by choosing to participate in educational activities (Welburn *et al.*, 2015; Hoffmaster *et al.*, 2016). The small sample size within the bat workers survey means that the low level of negativity experienced may not be a true representation of the level of negativity resulting from the pandemic. Targeted research aimed at gaining greater insight into the attitudes of specific groups would inform conservation education efforts. Negative attitudes towards bats already exist in sectors such as construction which can have devastating outcomes for bat populations (Bat Conservation Trust, 2019), so increased levels of negativity have the potential to exacerbate this issue.

Limitations

The limitation of online questionnaire distribution is the inherent coverage bias, limiting responses to those with internet access (de Leeuw, 2008; Tanner, 2018; Andrade, 2020). Sharing the questionnaires through social media groups provides no control over its distribution, and therefore the composition of the sample group, resulting in convenience sampling, where respondents self-select to participate, can share the questionnaire with others and can also submit multiple responses. There is also no option to differentiate respondent characteristics to select for a balanced sample (Tanner, 2018; Andrade, 2020). Questions in online surveys are also open to misinterpretation, lacking the opportunity for clarification and leading to incorrect responses (de Leeuw, 2008; Bernard, 2017).

The significant higher levels of interest in nature and opinion of bats could be a result of these limitations thereby creating a potential bias within the survey. Research has found that people are more likely to complete a survey if the topic interests them (Groves *et al.*, 2004; Saleh and Bista, 2017) which is an advantage in many cases. However, the aim of this survey was to obtain results from a sample with a broad spectrum of opinion, it was specifically not shared in bat or nature related groups to avoid such bias. In this case the title of the questionnaire, 'Bats, Covid and the Public', could have influenced the decision-making process of potential participants of the survey, appealing to those with an existing interest in bats and wildlife in general, and deterring those with less or no interest. The survey could be repeated using stratified random sampling to select a representative sample of the UK population to limit the potential for bias (Lazar *et al.*, 2017).

Conclusion

This study aimed to determine the impact the SARS-CoV-2 pandemic had on public perception of bats in the UK and the potential consequences for their conservation. The results demonstrate that, unexpectedly, overall opinion of bats increased, knowledge of their ecological importance was relatively high, and the level of negativity observed was low. However, some of these results may not be truly representative and can only provide an insight into the attitudes and opinions of the public. Assessing people's knowledge and attitudes can produce useful information to inform decision-making processes in relation to conservation education and bat management programmes, and education is fundamental to the success of bat conservation. The increase in nature connectedness and wildlife interest

through the pandemic provides an opportunity to direct that interest towards the conservation of bats. Addressing gaps in knowledge relating to the ecological importance of bats and the threats they face has the potential for increasing public attitudes towards them. However, care should be taken when attempting to debunk the misinformation surrounding the link between bats and SARS-CoV-2 as repeating the information, even to refute it, can inadvertently reinforce it. Further research within specific sectors could provide more robust data to design and target conservation education to maximise the potential success of bat conservation measures.

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Appendix A

In the words of Willie Nelson “Once you replace negative thoughts with positive ones, you start having positive results”.

Examples of comments received from public participants:
Learnt something new today, thank you!
This is very interesting information – thank you for educating me.
Thank you, I feel I have learned from this regarding the importance of bats.
Lots of interesting facts, I will be sure to drop some of these into conversations.
Did not realise that bats did so many positive things for the environment, very interesting.
Info on bats good to know.
I did not know the exact positives bats bring but liked them anyway. Thank you for teaching me something.
Glad I completed this survey was interesting to learn bats are pollinators.

Appendix B

Examples of comments received by bat workers from the public:
People asked if it was safe to enter their church and thought that they might catch coronavirus from UK bats, a few people in a specific location had been told that they could catch the virus from the bat droppings (by a professor no less).
A few contractors that were upset at the idea of being near bats due to their misguided perceived risk of catching covid-19 from UK bats.
How to remove bat roosts due to health concerns; why should they have to risk disease by having bats in their house.
Can't we shoot the bats if they may carry covid?
Site contractors concerned about catching covid on sites where bats are present.
Roofers during a supervised roof strip reacting negatively to the idea that bats might be present and talking about killing them if they found any.
Comments from home owners about why should they have to survey and mitigate for bats its their fault we have covid etc.
Asked by a passer by during a bat survey on a rail bridge in Workington if I was doing a bat survey so that they could cull the bats 'due to covid'. Have also had to reassure site workers that they cannot catch covid from bats. They were wearing masks on site nowhere near the roost in case they caught covid from the bats.
Can we remove them, we're worried about disease.
How to transfer/where to leave bats for collection.

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Twenty Years of Bat Box Checks in West Dorset – Volume One

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Introduction

In 2002 the Dorset Bat Group (DBG) began undertaking bat box checks along the Tolpuddle/Puddletown by-pass. Now, 20 years later, the project has grown. There are more sites, and more boxes, but those checks are still at the heart of the project and the anniversary felt like a good time to take a look at the data and see what it might tell us.

There is a lot of data, and as is always the case, the deeper you look the more questions that arise. As a result, the data will be presented in two volumes. This volume sets out the background to the project and some of the key findings. Volume Two (planned for publication in 2024) will look at some of the individual sites in more detail.

Background to the West Dorset Bat Box Project

Towards the end of the 20th century the A35 Puddletown/Tolpuddle bypass was built (Figure 1). This dual carriageway was built to reduce commuter traffic on the single carriageway road that ran through the two villages, from Bere Regis to just east of Dorchester. Cutting through woodlands, water meadows and agricultural land to the north of the villages, the new road opened in 1999. To make way for the new road, two houses, which had been used as a transitory roost by brown long-eared bats *Plecotus auritus*, were demolished and a significant number of mature deciduous and coniferous trees were removed along the route.



Figure 1: Location and approximate extent of the Puddletown/Tolpuddle bypass.

The road contractor (Balfour Beatty) sought advice with regards the provision of alternative habitat, as mitigation for the loss of roosts resulting from the building of the bypass. As a result, 119 boxes (Schwegler 2FN woodcrete boxes) were bought by the contractor and donated to DBG who erected them in woodlands along the route of the bypass.

Ten woods were originally identified (by the contractor) as targets for bat box installation. These woods were inspected by the group and two were rejected as being too dense to allow the erection and inspection of boxes. Shortly after box installation was complete, a third woodland was also rejected, for similar reasons and the boxes were re-sited. Of the remaining woods, one was up to half a kilometre from the route of the road, while the rest were within 200m or so of the route of the bypass.

The boxes were originally erected in 1996/7 on the understanding that they would be checked on five occasions spread over three years and during that period small numbers of bats¹ were occasionally found. After the last survey (September 1998) the boxes then remained unchecked until the group restarted the checks in spring 2002.

After some initial checks to map the boxes and, in many cases, clear them out, the group began to check the boxes regularly and it became clear the boxes at four sites were not being (and had not been) used by bats. These boxes were re-located, either to existing sites within this scheme or to sites nearby since incorporated into the West Dorset Bat Box Scheme. The locations of the woodlands where the boxes were originally placed are shown in Figure 2, with the blue circles being sites from which the boxes were re-deployed and the red circles being the sites where boxes are still checked today.



Figure 2: Location of bat boxes deployed along the route of the Tolpuddle/Puddletown bypass.

Since 2002 the original three sites have been added to, there are now seven sites that, together, form the current West Dorset Bat Box Project. The date in brackets is the year the site was first incorporated into the West Dorset Bat Box project:

- Tolpuddle Ball Wood (2002)
- Roger's Hill Farm (2002)
- Bardolf Manor (2002)
- Thorncombe Wood (2003)
- Ryewater Nursery (2006)
- Carey House (2021)

A seventh, confidential, site was incorporated into the project in 2006. In order to preserve that confidentiality, the site, near Bovington, is referred to as Site X in the text.

¹ Brown long-eared bat, noctule *Nyctalus noctula* and *Pipistrellus* species bat.

The approximate locations of the West Dorset Bat Box project sites are shown in Figure 3, with the blue stars representing sites where boxes were originally installed, in 1996/97 (prior to the project starting) while the red stars representing sites added since the West Dorset project started.

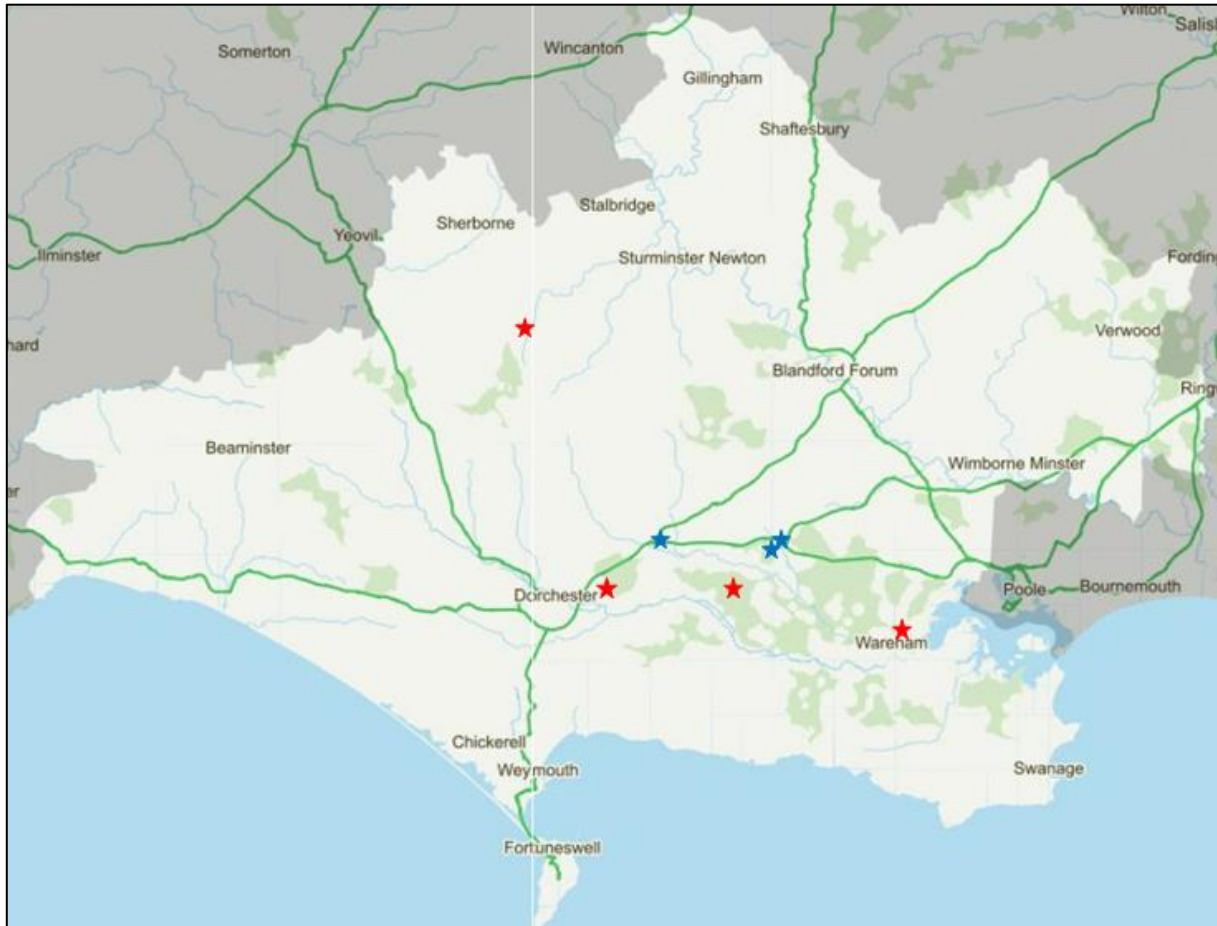


Figure 3: Location of sites for the West Dorset Bat Box Project.

Originally all the boxes in the scheme were Schwegler 2FN (cavity boxes) but, in 2019, a number of Schwegler 1FF (crevice boxes), along with some additional Schwegler 2FNs, were installed at Carey House (funded by Mark Constantine). In 2021, following discussions around the often-limited availability of Schwegler boxes, and what suitable alternatives might exist, a range of alternative options were installed alongside the existing boxes at several of the project sites (and at other sites outside the project).

As a result of this investment, the project now involves a total of 215 boxes, spread over seven sites, with the boxes checked seven times a year, from March to September inclusive² (from 2023 onwards an eighth check, in October, will be included).

² Initially the boxes were checked four times a year (March, June, September and December) but the December checks were stopped in 2009. If it was mild in December we found (active) bats, if it was cold, we did not. Presumably the bats were simply reacting to the weather and retreated to a place more suited to hibernation when the weather turned cold, but increasing concern over disturbing them at a highly vulnerable time of year meant checks in winter were stopped.

Although the West Dorset Bat Box Project represents a significant investment in time and resources, it is important to remember that there are many other sites across the county where bat box checks take place.

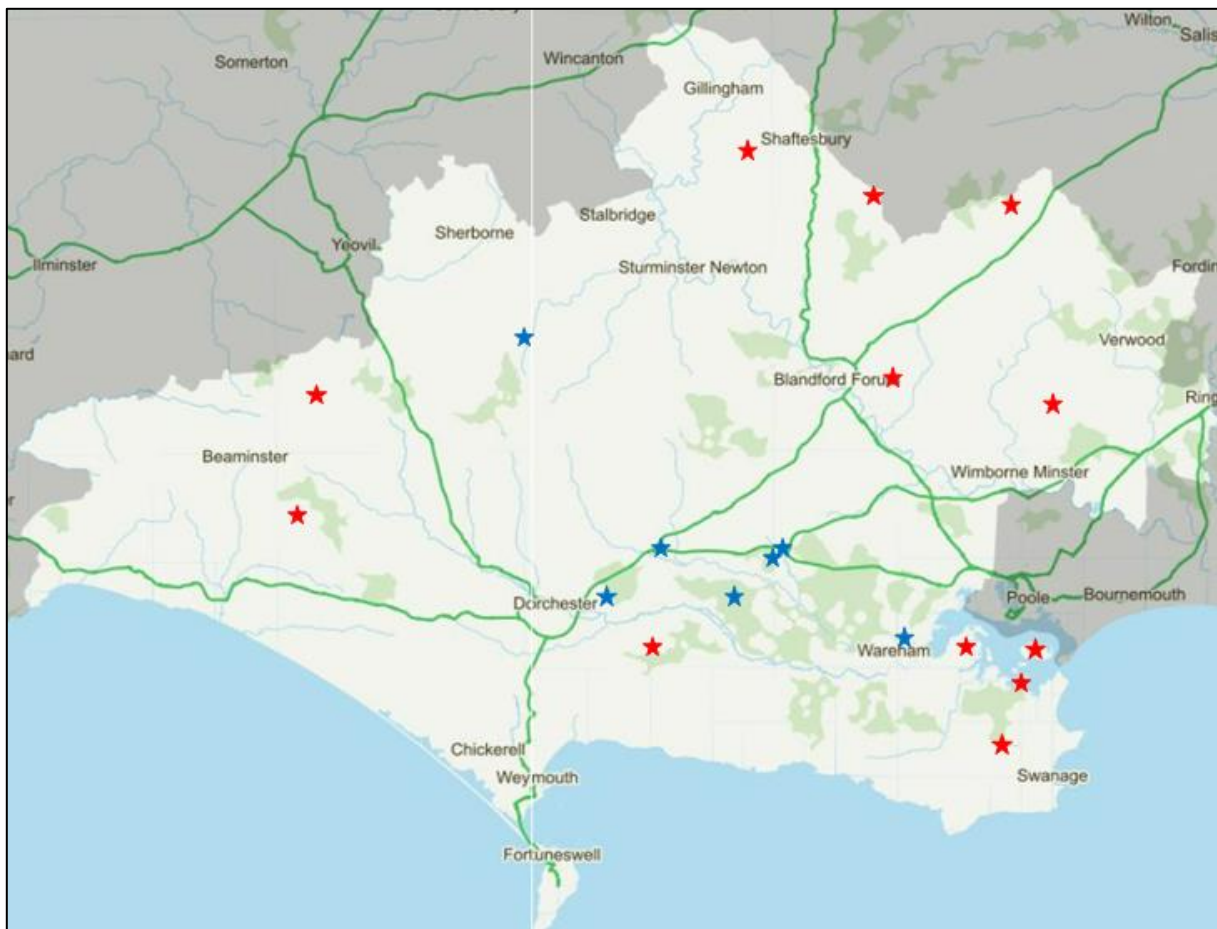


Figure 4: Location of bat box schemes across Dorset (with blue stars showing the sites in the West Dorset Bat Box project, for context).

Therefore, to put the West Dorset sites in some form of context, Figure 4 shows 19 of the 21 known sites where bat box checks take place in Dorset that either involve members of DBG, the Dorset Wildlife Trust (DWT) or the RSPB. At these 21 sites (which include three DWT and two RSPB reserves) a total of 1,088 bat boxes are checked, with numbers of boxes at individual sites ranging from seven to 145, with an average of 52 boxes.

Please note: While other bat box schemes are known to exist within Dorset, the author does not know the locations of the sites or the number of boxes involved, so they are not included in the figures above.

Overview of the woodlands involved in the project

Tolpuddle Ball Wood

An ex-shooting wood located immediately to the south of the A35. Shooting is believed to have stopped when the bypass was opened. The woodland as a whole is around 8ha in extent and is moderately well connected into the wider landscape south of the bypass. The

section in which the boxes sit is around 1.5ha in size and is largely conifer woodland, with a small broadleaved element and varying broadleaved understorey.

Roger's Hill Farm

An avenue of large, mature, lime trees, located to the north of the bypass and running around 200m from the main road north to the farm. There is little understorey and the avenue is only 15m wide, so it is quite windy and often noticeably cooler than Tolpuddle Ball Wood, which sits around 1km to the west. This effect is, perhaps, exacerbated by the canopy which, when in leaf, creates a densely shaded environment. The site is poorly connected into the wider landscape, with the largest blocks of nearby woodland located on the other side the bypass.

Bardolf Manor

A mixed broadleaved woodland, with many large, mature trees and a mixed understorey. The woodland, which is around 2.5ha in extent, could best be described as linear, as it runs along a driveway and around a large field and is around 50-60m at its widest. It is located just off a large junction on the bypass and is poorly connected into the wider landscape.

Thorncombe Wood

The boxes in this 26ha woodland are located in two sections, each around 1ha in size. One section is very open, with limited understorey, based around large mature beech and sweet chestnut trees. The other section has a much better developed broadleaved understorey and contains mixed age trees included some large mature oaks. The woodland is well connected into the wider landscape and is part of a large woodland complex.

Ryewater Nursery

The site as a whole is over 40ha, but the woodland where the bat boxes are located is around 4ha in size and is a mixture of coppice with standards and unmanaged woodland, with the boxes split between the two. The site is well connected into the wider landscape, including well wooded hedgerows and woodland blocks.

Carey House

A well-connected mixture of open gardens, large mature broadleaved trees and conifer woodlands, with broadleaved understorey, with the boxes split between these three habitat types. The site as a whole is well connected into the wider landscape, containing more extensive woodland and a large river corridor.

Site X

A large (c.45ha) mature woodland with many large oaks and with varying levels of broadleaved understorey. The boxes are scattered over an area of around 4ha, located towards the western edge of the woodland. The woodland is well connected out into a much broader landscape.

Analysis of the results

Poulton (2006) notes that with regards to the data used in his analysis 'the surveys from which the data were gathered were not designed as experiments to test specific hypotheses concerning bat box usage.' Sadly, neither was the current project so, as a result, we must be

careful not to look too deeply at the data, it is just not consistent enough. For instance, no checks took place in 2012, due to a Foot and Mouth outbreak and the Covid pandemic stopped any checks in 2020 and meant only limited checks in 2021. In addition, even in the years with no external constraints, it was sometimes not possible to visit all sites on all dates, due largely to resource availability. All these checks are done by volunteers and sometimes other things took priority.

However, even with those caveats, it is still interesting to see what the data reveals, or at least what it might hint at. What follows, therefore, is not intended to be statistically rigorous, but more of an overview of some of the more interesting aspects of the data.

Box usage

Between the project starting in 2002 and the 20th anniversary (in 2022) a total of 8,066 individual bat box checks were undertaken, where a check is the examination of one box on one date.

During these checks, a total of 4,291 bats were found, over 728 occasions, giving an occupancy rate (i.e. when a bat is found in the box) of 9%, although, of course, many of these bats will be the same animals encountered multiple times across the lifetime of the project and indeed, the lifetime of the bat!

In addition, in the same period, droppings were found on 1,099 of those individual checks (c.14%).

Taken together that means positive signs of bat use (i.e. either bats or droppings) were found on 23% of the checks in total, or, putting that slightly differently, on average we might expect to find signs of use in around one in four box checks.

In his study (involving over 68,000 records) Poulton (2006) gave an overall occupancy rate 8.7%, so the 9% above is very comparable. Unfortunately, that study did not go on to look at droppings, so the overall usage rate above cannot be compared.

Naturally the usage rates vary from site to site, Figure 5 shows the values for occupancy, droppings and combined usage, by site. The project averages for each of those categories are shown as dotted lines laid across the graph.

Clearly the individual site rates vary, but it is interesting to note that two sites, Roger's Hill Farm (RHF) and Site X, have all three categories at, or well above, the project averages, yet these two sites have the least number of boxes (seven and eleven respectively).

Dodds and Bilston (2013) noted that 'box occupancy.... was at its highest in areas with the greatest number of known tree roosts.' While that may well apply to Site X, there are very limited roosting opportunities (that have been found) at Roger's Hill Farm. Poulton (2006) notes that box height appeared to have a significant effect on box use, with a clear decline in use as height increased, with occupancy rates halving between 4m and 7m above ground.

Naturally the usage rates vary from site to site, Figure 5 shows the values for occupancy, droppings and combined usage, by site. The project averages for each of those categories are shown as dotted lines (of the same colour) laid across the graph.

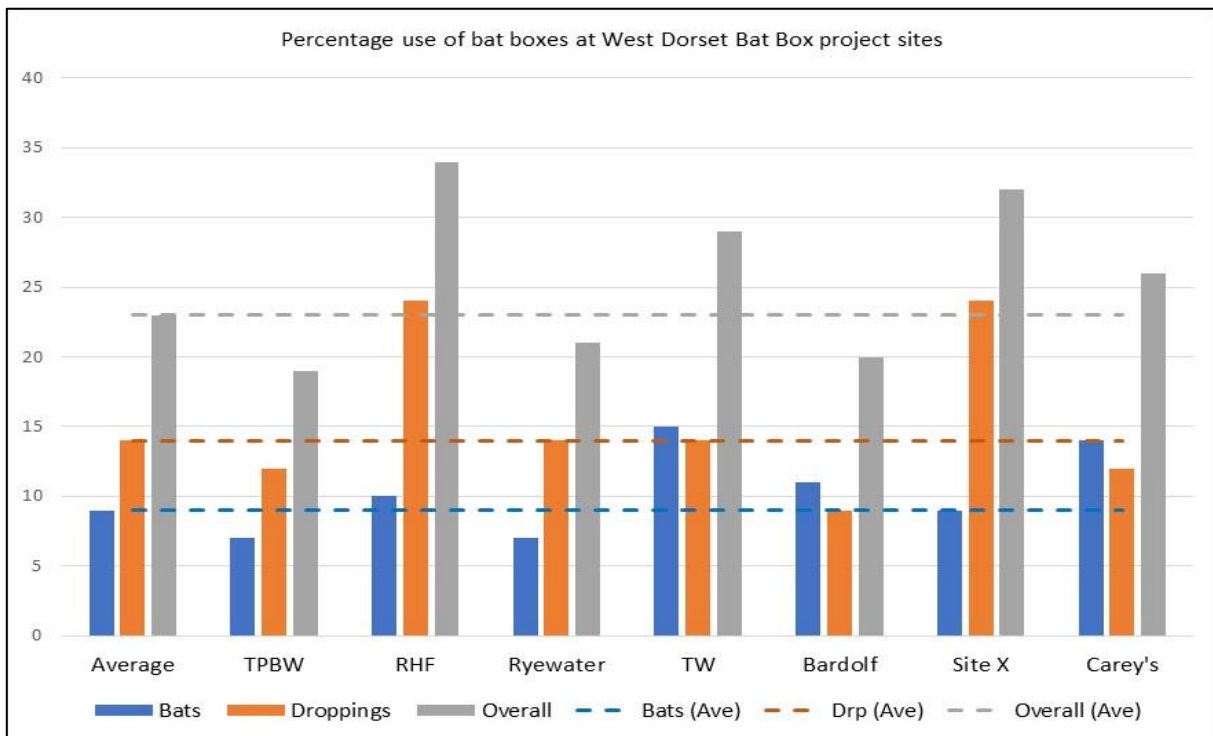


Figure 5: Percentage of boxes found to contain bats or droppings for each site in the project, overlain with the across project averages (dotted lines).

Species recorded

The bat species found during the checks over the last two decades are:

- Daubenton's bat *Myotis daubentonii*
- Natterer's bat *M. nattereri*
- Bechstein's bat *M. bechsteinii*
- noctule *Nyctalus noctula*
- common pipistrelle *Pipistrellus pipistrellus*
- soprano pipistrelle *P. pygmaeus*
- brown long-eared bat *Plecotus auritus*
- barbastelle *Barbastella barbastellus*

Of the UK's 18 bat species some, such as greater mouse-eared *M. myotis* are very rare, nationally, while others, such as Brandt's bat *M. brandti* are very rare locally.³ Still others, such as lesser horseshoe bat *Rhinolophus hipposideros* and greater horseshoe bat *R. ferrumequinum*, don't use bat boxes, while serotine *Eptesicus serotinus* and grey long-eared bat *P. austriacus* are not, generally, found in bat boxes.

³ Brandt's bat has been confirmed at three sites in recent years in Dorset and the species is considered to be rare throughout the county.

That leaves 12 species that have a reasonable chance of being found in bat boxes, of which eight (67%) have been found on the West Dorset Project. It is interesting to look behind the data and see what points may be teased out.

Volume Two will look at what the detailed, site level, data reveals, both within, and across, sites, but two tables (Tables 1 and 2) are presented here to allow some broad comparisons to be made.

Table 1: The highest single survey count of each species at each site (i.e. the total counts for that day, which may have occurred across multiple boxes).

	Mdau	Mnat	Mbec	Nnoc	Ppip	Ppyg	Paur
Tolpuddle Ball Wood		30		1	7	6	15
Roger's Hill Farm		35				5	1
Bardolf Manor	1	10		24	2	1	5
Thorncombe Wood		11		20		6	21
Ryewater Nursery		1	35		5	2	12
Carey House					1	14	14
Site X		56		10		3	12

Table 2: The number of visits to each site and the number of visits on which each species has been recorded.

	Surveys	Mdau	Mnat	Mbec	Nnoc	Ppip	Ppyg	Paur
Tolpuddle Ball Wood	59		34		2	1	27	41
Roger's Hill Farm	49		33				1	1
Bardolf Manor	66	1	21		20	2	2	2
Thorncombe Wood	67		14		32		18	10
Ryewater Nursery	66		1	44		7	10	39
Carey House	6					5	5	3
Site X	44		13		13		5	9

Thus, the highest count of Natterer's bats at Roger's Hill Farm is 35, and they have been recorded on 33 out of 49 visits (67%) to that site.

The data are drawn from across the whole project, 2002 to 2022, and the highest count at one site may have occurred on a different date (or indeed in a different year) to the highest count at another site. As a result, we need to be careful in drawing too many conclusions, however some key findings include:

- Daubenton's bats have only been found once, in more than 8,000 checks, despite two of the sites containing, or being near to, large water bodies
- The remarkable 56 Natterer's bats at Site X, on one visit, despite that site only having 11 boxes!
- While the peak numbers are not the same, brown long-eared bats are found at Ryewater almost as often as Bechstein's bats are
- Carey House has (very quickly) become a hot spot for *Pipistrellus* species in a short period of time

- There appears to be significant differences in the frequency of occurrence of the two *Pipistrellus* species across the sites

Equally, the occurrence of each species are not split evenly across all sites:

- Ryewater, for instance, is the only site where Bechstein's bats occur, while Natterer's bats have only been seen there once
- Bat sightings at Roger's Hill Farm have been exclusively Natterer's bats since 2005, with one record each of brown long-eared bat (one individual) and soprano pipistrelle (five animals) prior to that
- Noctules had, until 2022, never been found at Tolpuddle Ball, but there have been two records since (and a third in 2023)
- Brown long-eared bats were not recorded at Bardolf Manor until 2022, when a probable mating pair were found in a box there

It is perhaps worth exploring some of this in a little more detail.



Figure 6: Bechstein's bats at Ryewater Nursery.⁴

Bechstein's bat

Ryewater Nursery is the only place on the project where this species is found (Figure 6). Checks at the site started in 2006, and the first record of the species was in 2008, when a lone male and then five females were found on the same survey, raising hopes that a colony was using the site. Those hopes were soon dashed when one bat was found the next year,

⁴ Please note the small black dots in the lower left of Figure 6 are the pupal cases of a nycteribiid bat fly *Basilia nana* whose main (possibly only?) host in the UK is the Bechstein's bat.

then nothing for three years. In the fourth year 15 animals were found and the numbers have grown, slowly, ever since (Figure 7).

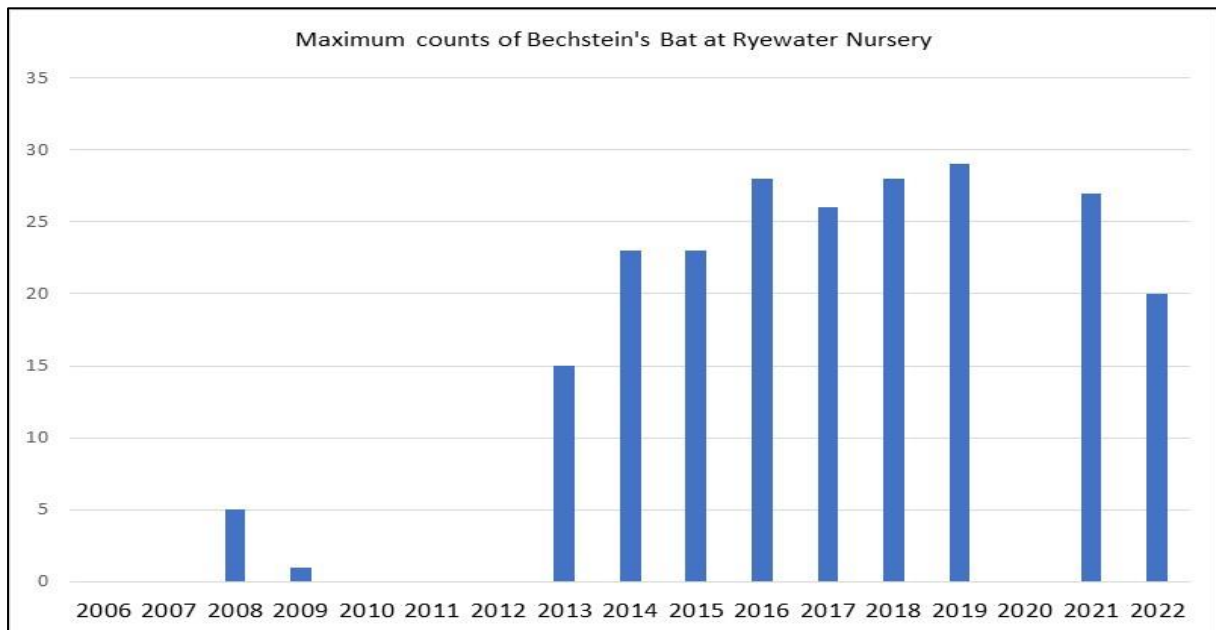


Figure 7: Maximum annual counts of Bechstein’s bat at Ryewater Nursery.

Ryewater Nursery is a mixture of unmanaged woodland and active coppice, with the boxes split more or less evenly between the two, although the boxes in the unmanaged part of the site have been up for less time than the remainder in the managed coppice, so have been ‘colonised’ quite quickly.

One interesting aspect of their behaviour is that, while radio tracking studies have shown the bats do not forage in the coppice areas, they appear to use the boxes quite readily, although not as regularly as the unmanaged areas. It may be the additional heat the more open nature of the coppice area allows, through increased insolation, is attractive to them. This will be explored further in Volume Two.

Looking at Table 1, two things jump out; brown long-eared bats are found almost as often as Bechstein’s bats (albeit in smaller numbers) and Natterer’s bat has only been found in the boxes once at Ryewater Nursey.

Some years ago concerns were raised about the installation of bat boxes to study Bechstein’s bat, as it was feared the boxes might attract competitors from among the commoner species, such as *Plecotus* bats, which might then impact on the population of the rarer Bechstein’s bat.

Studies have since shown that, largely speaking, the two species forage in different parts of the woodland, so can comfortably co-exist. That certainly seems to be the case at Ryewater Nursery, where *Plecotus* bats were recorded before Bechstein’s bat. It may even be that the increase in Bechstein’s bats has resulted in a reduction in the numbers of brown long-eared bats using the boxes (Figure 8). If true that would be quite a twist on the original concern!

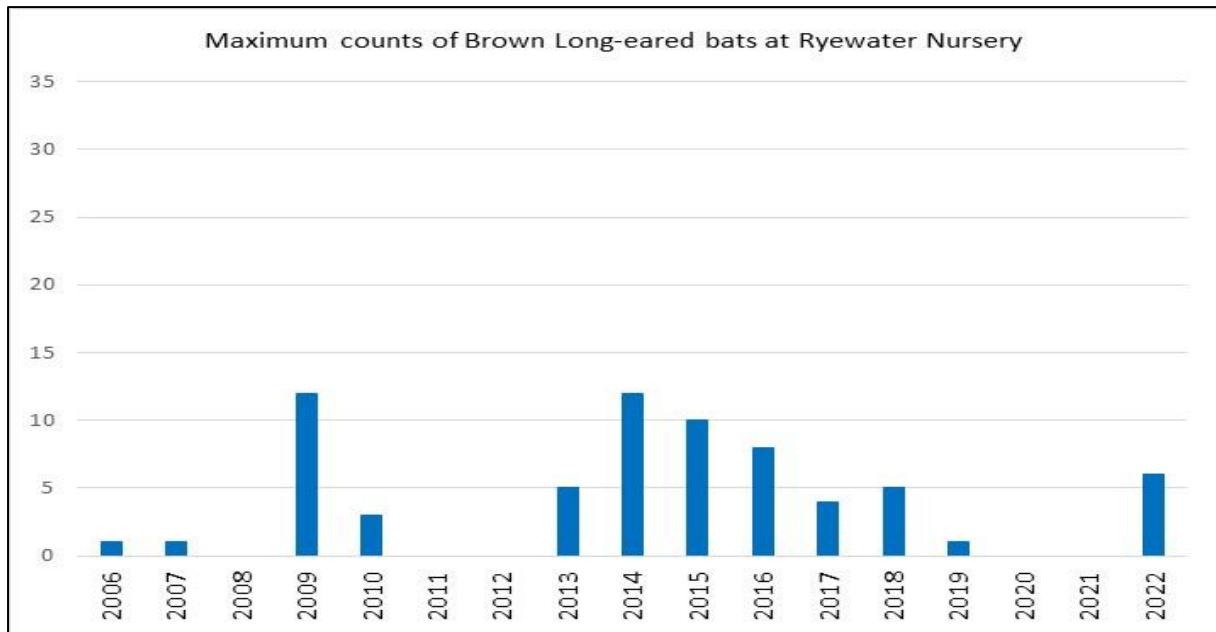


Figure 8: Maximum annual counts of brown long-eared bat at Ryewater Nursery.

The habitat at Ryewater would seem, on the face of it, to be perfect for Natterer’s bat and they are recorded in boxes in similar habitat elsewhere in the project (Figure 9), yet the species has been recorded in the boxes at Ryewater only once. It is possible, given their sudden appearance in the boxes at other sites (see below) that they have not yet ‘found’ the boxes, but could it also be possible the slightly larger Bechstein’s bats are keeping them at bay? Perhaps the next few years may give us some answers.



Figure 9: Natterer’s bats in a bat box (please note the younger, grey, bats in the middle of the cluster).

Natterer’s bat

The project currently has three main sites for Natterer’s bat (Roger’s Hill Farm, Tolpuddle Ball Wood and Site X) where they are found in good numbers, with counts, typically, ranging from late-teens to mid-twenties and sometimes higher.

Interestingly, although species such as noctule, *Pipistrellus* and brown long-eared bat have been found at most of the sites, almost from the start of the project in 2002, for several years Natterer's bat was not recorded at any of the sites, **at all**.

Then, in 2006, four years after we started checking the boxes, we found our first Natterer's bat, for the whole project, at Roger's Hill Farm and they have been found there, in most years, ever since. While there have been ups and downs, the overall trend, in terms of average number of bats seen, has been upwards since that first sighting (Figure 10).

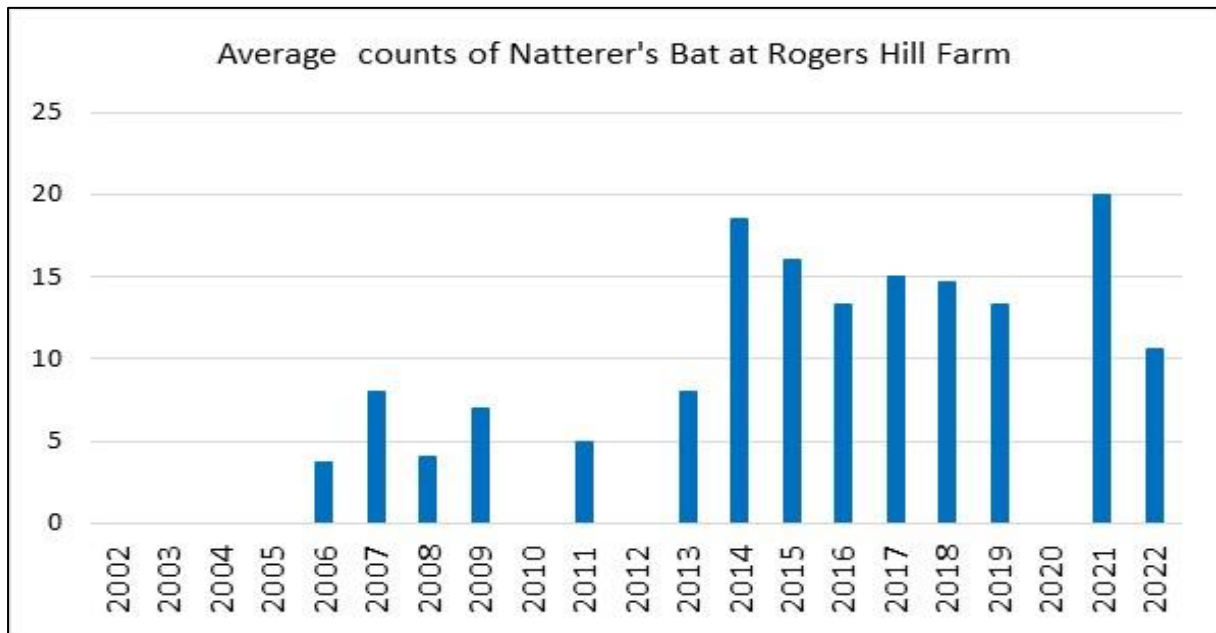


Figure 10: Average number of Natterer's bats found, by year, at Roger's Hill Farm.

Another one of the project's 'main' Natterer's bat sites is Tolpuddle Ball Wood. Interestingly, Natterer's bat were not recorded there, in numbers, until 2013, after which numbers rose rapidly and, today, a typical group would contain around two dozen animals. As with Roger's Hill Farm, the trend, in terms of average numbers found, appears upwards (Figure 11).

At our third 'key' site for the species, Site X, the picture is less clear. They appear to show a similar pattern to Tolpuddle Ball Wood, with the animals taking a little while to be recorded regularly, and with the trend, in term of average numbers being positive. There have, however, been several occasions where, for a variety of reasons, checks were not possible, so we do not have as continuous or clear a data set for this site (Figure 12). This will be explored further in Volume Two.

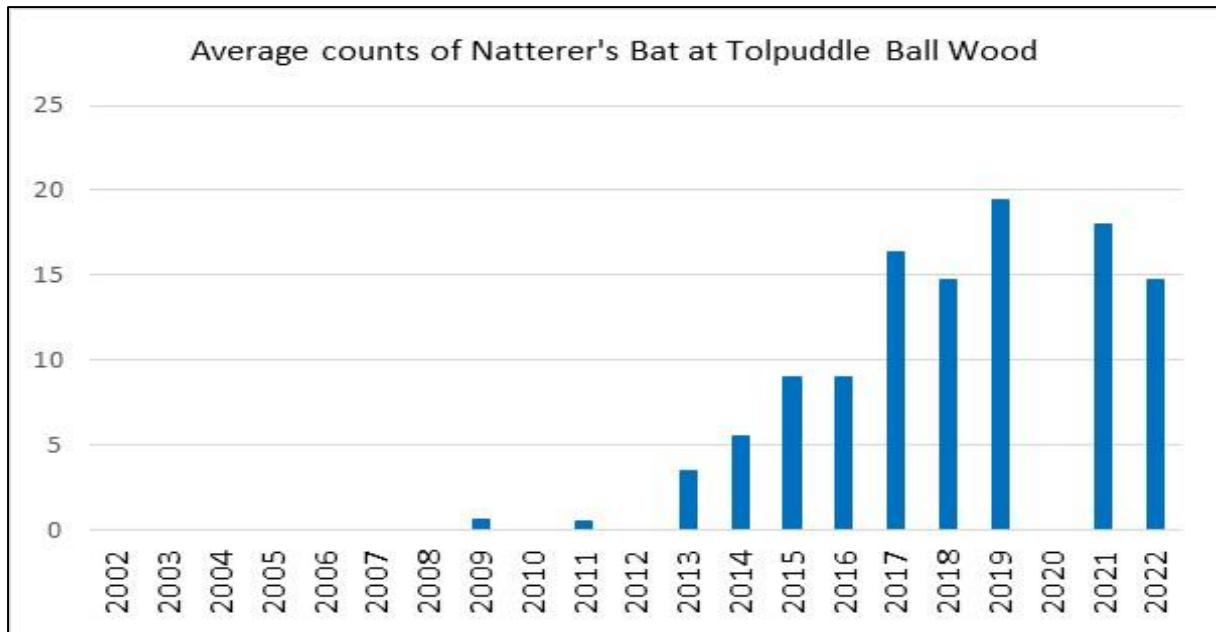


Figure 11: Average number of Natterer’s bats found, by year, at Tolpuddle Ball Wood.

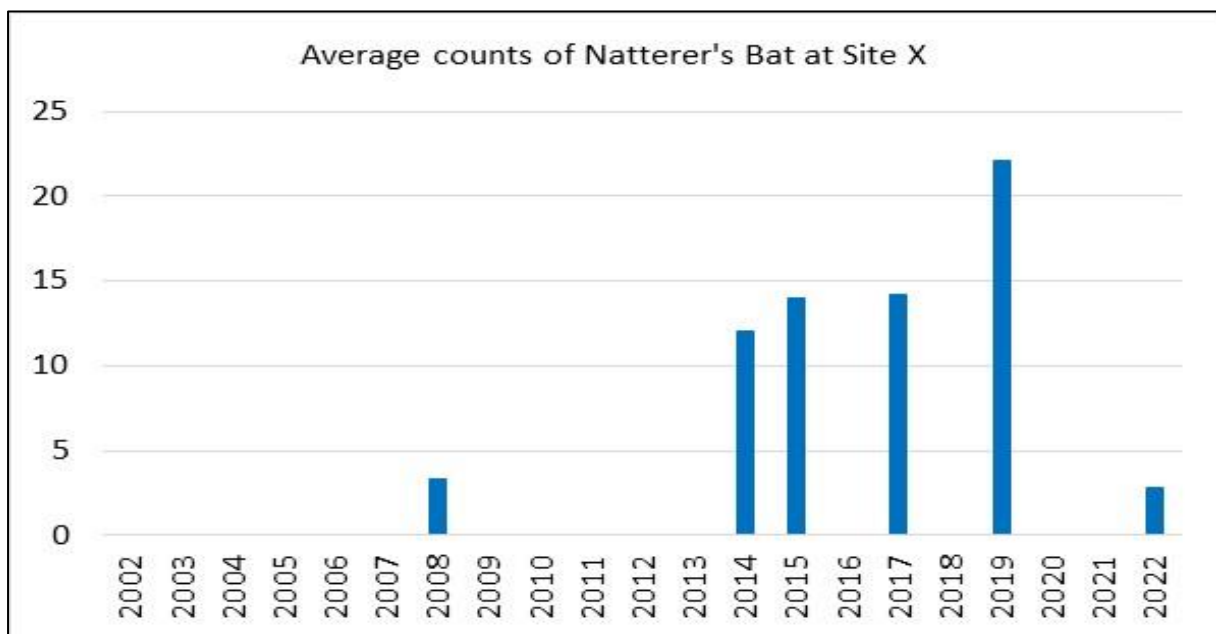


Figure 12: Average number of Natterer’s bats found, by year, at Site X.

In terms of the other sites where the species is found:

- Natterer’s bat were not seen at Bardolf Manor until 2006, thus showing a similar timing to Roger’s Hill Farm, although the numbers have not increased in the same way
- They were not recorded at Thorncombe Wood until 2013, thus showing similar timing to the take off at Tolpuddle Ball Wood, although, again, the numbers are not comparable
- It is known that at least one other site, not in the project, had a similar sudden appearance of the species

Why these sudden appearances should occurred is not at all clear.

Poulton (2006) notes that the time to use varied considerably, from dozens of days to ten years, but offers no explanation as to why, so the drivers behind three geographically separated sites⁵ all being colonised in the same three-year period remain unclear.

One interesting difference between Tolpuddle Ball Wood and Roger's Hill Farm is the weight of the bats in spring and the apparent effect this has on birthing dates.

Roger's Hill Farm is on the northern side of the A35 dual carriageway but the avenue of trees that hold the boxes is around 30m lower than Tolpuddle Ball Wood, which is situated on the southern side of the A35. A tributary of the river Piddle flows through the trees and, when in leaf, they create a dark and shady space. With almost no understory, there is also often a wind blowing through the trees, making the site noticeably cooler than Tolpuddle Ball.

Probably driven by these conditions, the average weight of the bats at Roger's Hill Farm in spring are consistently between 0.4g and 0.5g lower than those at Tolpuddle Ball and, in most years for which we have the data, the young are born around a week later, suggesting those conditions have a direct and measurable effect on the time of breeding of the colony.

The survival and recruitment of young into the adult population year on year at these two sites, and whether it is affected by the same conditions, will be explored in Volume Two.

Pipistrellus species

Along with brown long-eared bat, the soprano pipistrelle (Figure 13) is the most ubiquitous species in the project, being found at every site, while the common pipistrelle is only found at around half the sites, and on much fewer occasions (15 visits as against 68 for soprano pipistrelle) yet both species are widespread in the county.

Until recently, all of the boxes on the scheme were Schwegler 2FNs and anecdotal accounts of sites where, like the West Dorset project, Schwegler 2FN boxes dominate, suggest common pipistrelle are a rare sighting.

A site that is no longer part of the West Dorset checks, but which has a range of crevice and cavity boxes, may help to shed some light on that apparent bias. The data from that site suggests that common pipistrelle appeared to favour crevice boxes (like the 1FF), or cavity boxes that also have a crevice (like the Schwegler 1FD or 2F) and appear to avoid pure cavity boxes like the Schwegler 2FN. That same data suggests soprano pipistrelle may be a little more catholic in its box choice.

⁵ Tolpuddle Ball Wood and Roger's Hill Farm are around 1km apart but are on opposite sides of the A35 dual carriageway. While there is an underpass at the end of the avenue of trees at Roger's Hill Farm, static detector work looking for bat movement over the road or through the underpass, has shown no movement between the two sides. We have also been ringing at the two sites since 2016 and have had no movement of ringed bats between them. Taken together that is considered to demonstrate that the two sites must be considered as separate sites with regards Natterer's bat use.

In his report, Poulton (2006) states, with regards *Pipistrellus* ‘there was a very strong avoidance of the 2FN types, with much lower occupancy and bats counts.’ He also notes ‘pipistrelles appeared to favour 2F boxes, by using them much more quickly and then having higher occupancy and counts.’ However, it appears that many of the records he was dealing with had only recorded *Pipistrellus* to genus level, so the results may not be directly comparable.

It may, therefore, simply be the fact the vast majority of the boxes on the project are Schwegler 2FN (pure cavity) boxes that explains the limited number of common pipistrelle records.



Figure 13: Soprano pipistrelle bat in a bat box.

With the installation of both cavity and crevice boxes at Carey House, and the introduction of a range of new bat box models across the project (and elsewhere), some of which contain baffles to create crevices, it will be interesting to see if, over time, these boxes can add to this discussion. It is also interesting to note that, if this apparent preference is shown to be real, and cavity boxes are avoided by common pipistrelle, that could have relevance with regards boxes provided for mitigation purposes.

Daubenton's bat

This species (Figure 14) has been found at only one site, Bardolf Manor, and on only one occasion (in December 2005).

Bardolf Manor is around 600m from the river Piddle corridor, ideal Daubenton's bat habitat, but that corridor is on the opposite side of the A35 dual carriageway, which may act as a barrier for bat movement. In addition, Bardolf Manor is not that well connected into the wider landscape, which may also explain the relative scarceness of other species (Natterer's bat have been found there more often than noctule, although it is usually in ones or twos).



Figure 14: Daubenton's bat.

This one bat was found very close to the start of the project, so human error in identification cannot be ruled out, but it is believed that a more likely factor is the presence of noctules that results in the lower occurrence of other species. A similar effect is seen at Thorncombe Wood, where the boxes that are, typically, used by noctules, rarely have other species in them, and when they do, it is, typically, in small numbers.

Whether that is due to the size of the noctules or the smell that normally accompanies the bats remains unclear. This will be explored further in Volume Two.

Noctule

Two sites, Bardolf Manor and Thorncombe Wood, are the main sites for noctule (Figure 15) in the project. Typical checks in autumn at these sites would reveal several boxes, each with one (usually highly vocal and defensive!) male. Most of the boxes would contain very few droppings but one, sometimes two, would be found to contain large amounts of very smelly droppings.

Dietz *et al.* (2009) talks about males attracting 'usually 4-5, but also up to 20 females, who spend 1-2 days there.' The large amounts of droppings in the boxes was therefore taken as an indication that a male had been successful, and the males in those boxes that contained very few droppings had not been.

This led to these two sites being considered as mating sites, the only confirmed such sites in Dorset. Field work in preparation for a presentation at the National Bat Conference in 2006 suggested the males from the two sites may spend the summer together in Thorncombe Wood, but this has yet to be confirmed.

Autumn checking of the boxes in recent years has shown less of these signs, so there is some concern as to whether they are still being used. A programme of additional box checks and activity surveys is planned for 2023 to try and assess this and the results of that study will be included in Volume Two.



Figure 15: Noctules in a bat box.

Bats and birds

Bird nests are found in bat boxes on most sites, although, interestingly, much less where the site is a known noctule site, such as Bardolf Manor or Thorncombe Wood. These nests, if inactive, as judged by time of year and state of nest, are cleared out each year, usually in late autumn.

At Roger's Hill Farm, in July 2021, a group of bats containing an estimated 19 animals, was found above an inactive bird nest. The group was seen to contain young which, at the time, were considered to be too small to ring, so the group was not disturbed.

This is one of only a few times bats have actually been found above a bird nest, although old nests are often found to contain droppings, suggesting the occupation of boxes containing bird nests is a relatively common occurrence. The presence of a nest does not appear to prevent or deter access, even where it contains a lot of material (Figure 16).



Figure 16: Examples of bats found roosting above inactive bird nests (left, Natterer's bat, right, noctule).

Bats have also been found above an active bird nest, i.e. one containing live young or an adult on eggs, but only on one occasion, involving two brown long-eared bats. The species of bird was not noted(!) but is likely to have been a member of the tit family, which are, by far, the commonest species found nesting in bat boxes on the scheme (although nuthatch *Sitta europaea* seem to favour the large Schwegler 1FW hibernation boxes!).

The number of bird nests found in a given year will depend, to some degree, on the population density of breeding birds in the area in that year. At one site, which has a bird box monitoring scheme in place, discussions with the bird ringers have shown the greatest number of nests found in the bat boxes coincides (perhaps unsurprisingly) with the bird box occupancy being at its highest, suggesting good winter survival rates creating a premium on bird nesting opportunities.

The number of bird nests found, however, also varies depending on the site, and those boxes regularly used by noctules (Thorncombe Wood and Bardolf) have far fewer bird nests, even in peak years, when compared to boxes not used by the species, and in many years these boxes have no bird nests at all.

It is assumed this is due to most nests being those of blue tit *Cyanistes caeruleus*, coal tit *Periparus ater* and great tit *Parus major* and these species, especially the first two, would, it is assumed, be no match for an angry noctule. It is also possible the smell associated with noctules may act as a deterrent to birds using the boxes.

It could, of course also be related to the presence of natural nesting sites in those woodlands, as they have a far greater number of broadleaved trees, at both sites. The number of bird nests found across the project has, however, declined as noctule use has become established, so the presence of large bats, with large teeth, is believed to be the prime cause of the limited number of bird nests.

An exploration of the possible relationship between bird nests and the presence/signs of bats will be explored in Volume Two.

Bats and spiders

While there have been reports in the press of False Black Widow spiders *Steatoda nobilis* appearing to catch bats (Dunbar *et al.*, 2022) spiders webs do not appear to put bats off using a box, even if the webs are quite thick (Figure 17).



Figure 17: Example of a bat found roosting in a box containing spider webs.

The species producing the web in Figure 17 is unknown, neither is it known if the bat entering the box causes the spider to leave but, interestingly, no bat has yet been recorded in a box containing an active spider nest, i.e. one with a spider still in situ.

Other occupants of bat boxes

As well as birds and spiders, other occupants found include mice, usually, wood mouse *Apodemus sylvaticus* but occasionally dormouse *Muscardinus avellanarius*, bees and wasps/hornets (Figure 18).

The occurrence of nests of all kinds go through cycles, which presumably reflects the population fluctuation of the nest builder, and in some years, nest building can reach extraordinary levels. In one year, at Ryewater, all the boxes that were located in the open coppice and some boxes on the edge of the unmanaged woodland, were occupied by wasps or hornets, with the hornet nests, in many cases, filling the box up and overflowing around it (Figure 18).



Figure 18: Examples of a nests in bat boxes (left, wood mouse, centre, bee and right, hornet).

The trend in mammal nests does show some cyclicity, but, overall, it is possible it might be declining (Figure 19), perhaps due to the increase in bat use of the boxes in that same period.

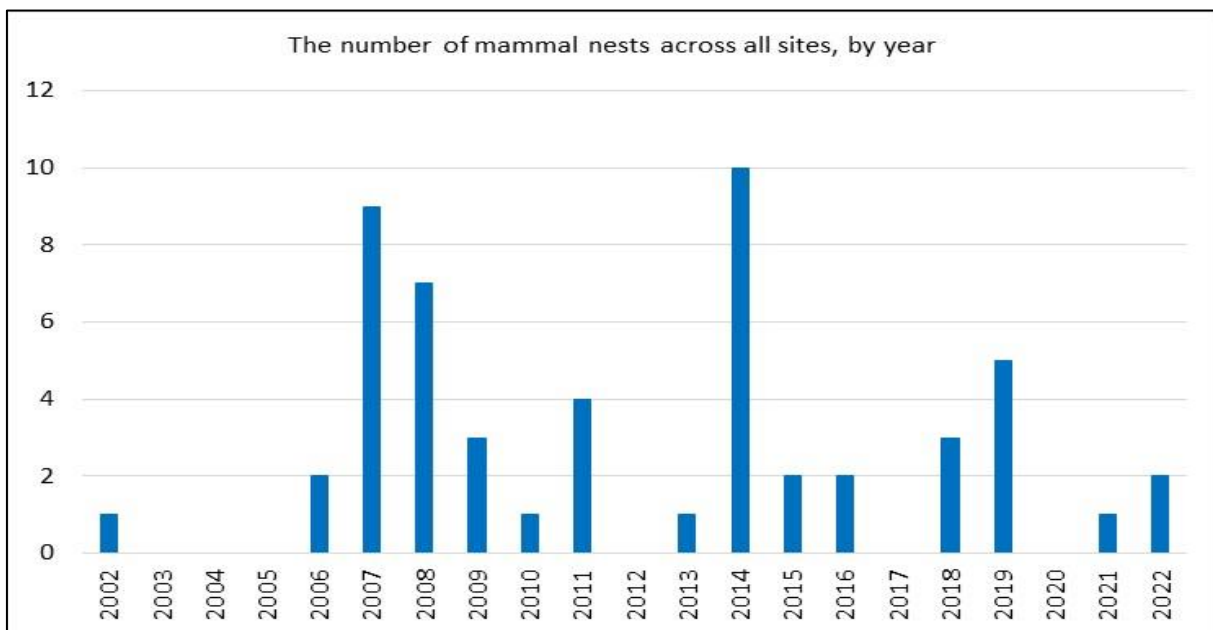


Figure 19: Number of mammal nests by year.

Volunteer numbers

Over the last 20 years these checks have helped build our understanding of bats and bat distribution in Dorset. They also provide a great training opportunity for those interested in bats and participants can expect to see something like 50% of the UK bat fauna, including rare species like Bechstein's bats. These checks are also a great opportunity to improve

identification and handling skills, both things which can be challenging to accomplish, but, perhaps most importantly, they are great fun!

They do, however, take a lot of work and over the twenty years, more than 140 individual volunteers have taken part in the surveys. Some of these volunteers have attended for only a few visits, others have become regulars and one or two have attended nearly every check in that time. While there are too many people to name them all, there are a few that deserve special mention and I would specifically like to thank the following for their continued dedication, help, good humour and support, without which the project could not have achieved what it has:

- Pete Banfield, who was instrumental in setting the project up and has been a key part since it started, attending nearly every single check, providing invaluable help and support
- Gaz and Liz Watkinson and Kevin Wood, who have become central to the project in the last decade, not only helping with the checks, but playing a key role in training those new to bat work in identification and handling skills.

Across the twenty years they have taken place, the volunteer time invested in **undertaking** these checks has been well over 500 days, or around two and a quarter working years! In order for the surveys to take place they need to be **organised** and the data gathered needs to be **processed** and assessed, which adds in yet more time.

While these checks are not undertaken for any financial gain, it is worth considering, for a moment, what that level of interest and input equates to, in terms of financial value.

The Heritage Lottery Fund (HLF) has figures that can be applied to volunteer time invested in projects funded by them, in order to equate a value to that time. Those HLF figures range from £400 a day for a professional volunteer (which would certainly apply to team leaders and those involved with the ringing) to £80 per day for unskilled volunteers. The mix of those categories has changed over the course of the project and especially with the development of a ringing programme in recent years, but, by taking the above numbers, and making some generalisations (for ease of analysis) the value of the volunteer time that has been invested in delivering the West Dorset Bat Box Project over the last 20 years works out to be a little under £120,000, a staggering amount!

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Learnings from the Bats in Churches project: simple solutions to complex problems

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Abstract

The Bats in Churches project is a five-year partnership between Bat Conservation Trust, Church of England, Historic England, The Churches Conservation Trust and Natural England. Funded by the National Lottery Heritage Fund, the project has worked with more than 100 ancient churches around England helping church communities find ways to live in harmony with their resident bats, as well as run engagement events and two major citizen science projects entitled the National Bats in Churches Study and Church Bat Detectives.

When the project began in 2019 it was anticipated that mitigation works for churches badly affected by bats would involve physically separating the bats from the church community (Arnold *et al.*, 2021), and in several cases this has been achieved successfully such as by the installation of sympathetically-designed false ceilings in the churches of St Lawrence, Radstone, Northants. and St George, West Grinstead, West Sussex. Such solutions are, however, large-scale, expensive, and require a licence¹, faculty permission² and other permissions.

Over the past five years the project has overseen a number of smaller, less expensive (and in some cases less permanent) solutions that have had a positive and lasting effect on church communities. In this paper we will explore some of these mitigation solutions and consider the learning from the project that in many cases smaller, simpler and cheaper solutions can be just as effective as large-scale capital works, with the end result that church communities live more harmoniously with a thriving resident bat population.

Success may also be defined outside of mitigation and constitute a reduced cleaning burden for the church, or more help with cleaning, and a church increasing its engagement with the community through its resident bats, even in cases where the presence of the bats causes practical difficulties for those responsible for caring for the church.

Introduction

Bats and churches have been associated for centuries. Many churches can live happily alongside their resident bats and even large roosts can go almost unnoticed. However, in some cases, having bats roosting or flying inside a church can cause serious problems for the church community, including an unmanageable cleaning burden caused by bat droppings and urine, disturbances to services and events, and damage to historic artefacts and the interior and fabric of the church.

Bats and their roosts are protected by law. Under the Wildlife and Conservation Act 1981 and the Conservation of Habitats and Species Regulations (as amended) 2017 it is a criminal offence to deliberately capture, kill or injure a bat, damage or destroy a breeding or resting

¹ <https://www.gov.uk/government/publications/bats-apply-for-a-mitigation-licence>

² The permissive right to undertake works to a church building or its contents
<https://facultyonline.churchofengland.org/type-of-works-you-can-apply-for>

place, obstruct access to a roost, shelter or resting place, and intentionally or recklessly disturb a bat in its roost or place of shelter. Where works cannot be carried out without causing an offence, a licence must be obtained from Natural England. This could be a full European Protected Species (EPS) Licence, or a class licence such as the Bats in Churches Class Licence which allows qualified and trained ecologists to directly manage ongoing work with low or temporary impacts on bats and their roosts.

The Bats in Churches project has worked with more than 100 of the worst-affected churches across England. The aim of the five-year project is to find ways to help church communities live in harmony with their resident bats, and this includes physical mitigation, help with cleaning and caring for historic items and the interior of the church, and engagement with the church and the wider community around bats.

The challenges of this approach are numerous and include; respecting and preserving the legally protected status of bats; respecting and preserving the heritage, historic and community significance of the church and its community; the resources available including funding, human resources and expertise; and understanding and managing the expectations of all parties who may have vastly different definitions of success. It remains the case that for some church communities, one bat is one too many.

Any alterations, additions or repairs to the fabric, fixtures and fittings of a church must also secure faculty permission from the diocese. Each mitigation solution has been different and bespoke to the church in question, just as issues faced are bespoke to the church and depend upon factors including size and species of bat population, how the bats are using the church, the location and layout of the church, attitudes among the church and community towards the bats, and motivation within the church community to proactively work in partnership towards a solution.

Success depends upon all parties – church communities, ecologists, buildings professionals, heritage professionals and anybody else involved in finding solutions – hearing and empathising with each others' perspective. A 'bats first' or 'church first' approach is unlikely to yield success in our experience.

For some of our project churches, the burden of cleaning up after the resident bat population coupled with other issues including ageing and declining congregations, rural locations and a lack of volunteers available to help care for the church have proved untenable and in at least one case, the church was closed when it became part of the project. In some cases the legally protected status of bats has led to church communities and those caring for churches to feel disempowered and not listened to when it comes to issues surrounding sharing spaces with bats.

Other churches, such as the church of St John the Baptist in Keyston, Huntingdonshire, have been home to rare and irreplaceable historic items and monuments which have been damaged by bat droppings and urine. St John's houses a rare 15th century wooden cadaver effigy which was uncovered and affected by bat droppings and urine. An inexpensive and permanent solution was found, and funded by Bats in Churches, in the form of a bespoke

oak and Perspex case to enclose and protect the cadaver whilst allowing it to remain visible as a key feature of the church.

Among churches there has been a wide variety of issues and a wide range of opinions and attitudes towards bats, ranging from a desire to exclude bats completely to a tolerance for their presence but a desire for help and support dealing with the issues bats present. A key learning from the project is that the presence of bats can have positive benefits for churches, even in cases where the bats cause practical difficulties, such as an increased cleaning burden, as well as the legal protected status of bats creating expense and additional consideration around maintenance, repair and capital works to the church.

The positive impact of bats can include increased engagement with the community including young people and families, fundraising events such as bat walks, a rejuvenated interest in the church building and its churchyard as a contribution to local wildlife conservation habitat and efforts, an impetus for volunteering, a point of interest to attract and engage visitors to the church, an opportunity to contribute to citizen science, and an inspiration for artistic, cultural and community events and activities.



Figure 1: Children from Netherseal School playing the ‘bat and moth’ game at an event run by a Bats in Churches Engagement Officer.

The Bats in Churches project in action

For most, if not all of our project churches, the starting point has been a need for practical solutions, ranging from major capital works to cleaning and conservation help with specific heritage items. In most cases, creating such solutions has involved bringing together relevant professionals including qualified ecologists, architects and building professionals together with members of the church communities, members of local bat groups and other wildlife organisations, and other interested and relevant parties.

In some cases, a Volunteer Bat Roost Visitor (VBRV) can offer education, advice and support to church communities, and the Bats in Churches project has worked with Natural England and the Bat Conservation Trust to support the training and development of VBRVs and increase the number who are willing and confident to visit a church and give advice. Any churches planning relatively minor works, or experiencing issues associated with a bat roost may be eligible for the free Natural England Bat Advice Service (BAS), under which VBRVs operate. The role of a VBRV is to offer a first point of contact and local support for churches including reassurance and education for those affected by or distressed by bats. Through the BAS, churches can be given advice on timings and methods for building maintenance work and pest control, and reducing the possibility of bats being excluded from their roosts. For relatively low-impact cases and where appropriate within the scope of the Bat Advice Service, VBRVs can offer a cost-effective solution for churches. For works outside of the scope of the service a visit by a VBRV is not a substitute for a survey from a qualified ecologist.

Case study 1: VBRV intervention and bat welfare

St Edmund's church in Eggleston, Rutland (Figure 2), is a Grade I listed church which has been a roosting site for bats for many years, but numbers rose dramatically over an eight to nine-year period and it is now home to the largest soprano pipistrelle *Pipistrellus pygmaeus* maternity colony monitored for the National Bat Monitoring Programme, with numbers peaking at 1,326 recorded in 2023.

Roosting in the nave roof void, the bats were able to access the interior of the church through small gaps and a sizeable hole in the ceiling where plaster had fallen off. This led to a large amount of droppings and urine scattered around the church, as well as an overpowering smell. There were also bat welfare issues, with some bats unable to find their way out and dying within the church.

Following surveys by a professional ecologist in 2021, a solution was proposed involving fixing the hole in the church ceiling and blocking a number of access holes, to prevent the bats from accessing the church interior. The Bats in Churches Engagement Officer contacted the National Bat Helpline to ascertain if the work could be done under a Natural England advice letter and VBRV supervision. Natural England subsequently advised in writing that this was acceptable and set out strict conditions for the work to be carried out under the VBRV's supervision, with the church raising ceiling repair funds and the Bats in Churches project contributing a requested sum of money for architect specification and a small shortfall. The work was completed in November 2022, securing the roost within the roof void and preventing the bats from accessing the interior.

Monitoring in 2023 found the bats are continuing to use the roost space in large numbers but are no longer accessing the church. Monitoring remains ongoing by the Leicestershire and Rutland Bat Group. The church has held dawn and dusk bat watching events and a community roost count. A Parochial Church Council (PCC) member also attended a church cleaning workshop run by the Bats in Churches project at nearby Braunston-in-Rutland.



Figure 2: St Edmund's church, Egleton, Rutland.

Case study 2: winning over hearts and minds

The Grade I listed church of St Margaret of Antioch in Wellington, Herefordshire, dates back to the 12th century and is considered to be of high archaeological, architectural and historical significance. Located in a rural area, it is an important feature in the local Wellington Conservation Area. Three species of bat have been recorded in the church – Natterer's bat *Myotis nattererii*, brown long-eared bat *Plecotus auritus* and soprano pipistrelle.

The Natterer's bats in particular had a big impact on the church community, including the presence of bats in the church interior, damage to items within the church, the impact on worship and community use, smell and a large cleaning burden from the widespread scattering of droppings and urine. A proposal to install a kitchen and toilet within the church was feared to be unlikely due to the impact of the bats. There was significant anti-bat sentiment among some of the congregation, although church users overall reported a positive attitude towards them. The ecologist engaged by Bats in Churches, Dr Alison Barnett MEnvSc, reported that on her first visit, she noticed a good deal of press coverage

on a display board within the church all focused around the negative impact of bats in churches.

Surveys revealed a maternity roost of Natterer's bats using several areas within the church and creating a great deal of mess and disturbance due to their roosting and social habits. Pews were covered with protective sheets to try and minimise the damage and it was clear the bats were causing a good deal of distress in terms of the cleaning burden. One cleaning volunteer reported they had been advised by their GP not to clean the church as the bat droppings and urine posed a risk to their health.

The Bats in Churches project allocated funding for the church (Figure 3) to pay for professional cleaners for two years during bat breeding season, to provide an immediate solution to the cleaning burden created by the bats. Dr Barnett recommended a droppings survey, which involved leaving the church for seven days before cleaning to ascertain the baseline against which success could be measured. This coincided with the COVID-19 pandemic, and Dr Barnett carried out the cleaning herself which resulted in improved engagement with the project from the church community once they could see the ecologist's direct involvement.



Figure 3: Bats in Churches project banner outside St Margaret of Antioch, Wellington, Herefordshire.

Following securing of faculty permission, mitigation works were carried out under a Bats in Churches Class Licence. The works included excluding bats from roosts in sensitive areas of

the church (Figure 4) to prevent droppings and urine collecting in well-used areas, and providing alternative roosting locations in different areas of the church in the form of under-eaves roost boxes. Boxes were designed in consultation with the church architect and provided a range of roosting opportunities with crawling spaces between sections to allow access to all roost features. Further roosting opportunities were provided by crevice and chamber boxes.



Figure 4: A cherry picker was needed for the works to close bat access to the interior of St Margaret of Antioch.

The mitigation did reduce the droppings accumulating in the church, although it did not eliminate them completely. However, by using the pre-mitigation droppings survey as a baseline, the ecologist was able to demonstrate that droppings reduced by 40% in the first year and by 75% in the second year post mitigation. The droppings survey proved more cost-effective than engaging a team of ecologists to survey over the duration of a few nights, and was able to provide evidence to the church community that the mitigation had an impact, even if it did not solve the problem completely.

The project engaged with the local community, with the Bats in Churches Engagement Officer running a workshop with the local school bringing children into the church to learn more about its bats. Through the project the church community engaged with wildlife groups within the village, using the churchyard as well as the bats. In May 2023 the church celebrated its wildlife through a community nature day attended by the ecologist, the local wildlife trust and mammal group, and other environmental organisations which attracted more than 100 visitors. One of the event organisers and churchwarden commented: “The event was everything I had planned and hoped for. There were lots of conversations with the wildlife groups who attended and a lovely relaxed atmosphere. It was an enormous effort but well worth addressing the negative feelings around living with our bat population”. As an added bonus the event raised more than £400 for church funds. Speaking at Bats in Churches Ecologists Best Practice Forum in April 2023, Dr Barnett said: “Although we may not have solved the bat problems entirely I consider this to be a success in terms of winning over hearts and minds.”

Case study 3: a novel and simple solution

St Mary the Virgin is perched on a rise above the pretty village of Pembridge, Herefordshire. The Grade I listed church dates back to the early 13th century and, alongside its associated separate bell tower, forms an important part of the Pembridge Conservation Area. It is rich in furnishings and fittings, including two fine 15th century chest tombs with pairs of effigies and the Pembridge Tapestries, which tell the history of the village from Norman conquest to present day.



Figure 5: Bat droppings and urine staining in the roof void of St Mary the Virgin, Pembridge, Herefordshire.

For many years St Mary's has housed a maternity colony of Natterer's bats with soprano and common pipistrelle *P. pipistrellus* and brown long-eared bats also having been recorded roosting in the church. Issues reported by the church community included bats in the church interior, damage to church artefacts and furnishings, droppings, an impact on community use, an impact on worship, and smell. Droppings and urine created a cleaning burden that sometimes required the church to be cleaned daily before use. Church users were broadly tolerant of the bats themselves (especially when using the roof void, Figure 5), but wanted to eliminate the negative impacts. The church also wanted help raising awareness of the importance of the church among the wider community for bats and biodiversity.

Following surveys, mitigation works were carried out with faculty permission and under the Bats in Churches Class Licence. These included blocking roosts in areas identified as containing important monuments and the enclosure of a roosting area, which had been used as a maternity roost, using wooden boarding and providing access holes for the bats (Figure 6). This allowed the roost to be used by bats without droppings and urine falling into the church below. Alternative roosts in the forms of eaves boxes designed with the church architect, along with crevice and chamber bat boxes, were installed with a range of interior and exterior access points and with sliding doors to offer the option of enclosing the roost in the future to prevent bats accessing the church interior. These doors were initially left open to allow the bats to familiarise themselves with the roost.



Figure 6: New roost compartments installed at St Mary the Virgin, Pembridge, Herefordshire.

Droppings surveys revealed that post-mitigation the mass of faeces collected in the church interior reduced by 40%. Subsequent surveys showed a variation in mass of droppings, which suggested bats were using St Mary's in a complex manner and in particular the Natterer's bat population which appears to regularly switch roost locations, and further adjustments may be needed. The enclosure of the Natterer's bat roost was partly successful but bats were roosting directly over the access hole, meaning droppings were still falling into the church which necessitated further work to alter the design of the enclosure and access hole to prevent this. Surveys are continuing to monitor the bat population at St Mary's and ensure the favourable conservation status of the bats.

Alongside the local mammal group, the church and ecologist hosted a bat night in 2019 (Figure 7), and this year the church held a weekend bat watch and children's activities event to coincide with Love Your Burial Ground Week. The Bats in Churches Engagement Officer ran school workshops with the local village school which were enthusiastically received. Interpretation has also been provided describing St Mary's involvement with the Bats in Churches project. To assist with cleaning the Bats in Church project provided funding for a hand-held vacuum cleaner to reduce the cleaning effort.



Figure 7: A talk to the St Mary's church community as part of a 2019 bat night event.

Feedback from the church community suggests that despite the original problem not being fully solved, they consider the project a success and that members of the PCC and congregation are now able to recognise that the church can be used by both congregation and bats, and that most but not all congregation members have engaged with this.

Case study 4: easing the burden

St Andrew's church in Coston, Leicestershire, is a distinctive medieval Grade I listed church with features dating back to the 11th century. The church is home to many fine medieval details and an unusual and striking bronze plaque commemorating the son of a rector who died whilst acting in a play. A sizeable maternity colony of Natterer's bats use the church and leave large quantities of droppings and urine throughout the church, causing a heavy burden to the small church community and creating a considerable smell.

Following a bat survey, ecologist Barry Collins proposed a series of trays positioned under the roost in the south aisle to catch the droppings and make the cleaning burden easier for the church. Faculty permission was granted for temporary trays to be installed in 2021 (Figure 8) under a Bats in Churches Class Licence. During the season Mr Collins used trail cameras to observe bat behaviour and alter the trays accordingly to find the best positions.



Figure 8: Trays being installed in St Andrew's church, Coston, Leicestershire.

The trays successfully caught droppings and reduced the cleaning burden on the church, although they did not eliminate it completely. At one point the bat population moved to an alternative location in the church, thought to be caused by extreme heat in summer 2022. In November 2022 the trays were modified and, with faculty permission, installed as a permanent feature designed to be as unobtrusive as possible and painted to match the church interior. Some access holes were also closed.

The church is used for VBRV training and in 2021 the church ran a successful bat night with members of the local bat group. Bespoke interpretation has been supplied to the church to educate visitors about the bats and the work of the Bats in Churches project.

Conclusion

There have been a number of changes to the scope and work of the Bats in Churches project since its inception. Some of these have been heavily influenced by the COVID-19 pandemic, others have come about as a result of sharing best practice and learnings whilst also respecting the individual nature of each church and community.

A partnership approach with all relevant parties – ecologists, church communities, architects and buildings professionals and enthusiastic and engaged volunteers – has been central to the overall success of the project and the success of individual case studies. Not all mitigation attempts have been wholly or, in rare cases, even partially successful in solving the problems and issues created by bats in churches. However, in most, if not all, cases church communities have engaged to a degree with the project and recognised and appreciated the efforts of all parties. If nothing else an awareness of the complexity of the issues surrounding bats and churches has been achieved, and this has helped demonstrate how, notwithstanding the strict legal protections in place for bats, simply attempting to remove bats from churches is neither desirable nor, in most cases, possible.

Ultimately there is no one-size-fits-all solution for churches with bats, but the Bats in Churches project has learned that, in many cases, major mitigation works are best approached as a last resort not a starting point and that, just as all church buildings and church communities are unique, what counts as success will also be unique to each case.

Post-project, the Bats in Churches website www.batsinchurches.org.uk remains as a valuable resource for church communities with bats, ecologists and volunteers. The website houses case studies, information and advice, and downloadable resources ranging from engagement activities to cleaning guidelines. The site also hosts e-learning modules including bat ID training and including churches in the National Bat Monitoring Programme, planning and running events, working with churches, working with volunteers and much more.

Acknowledgements

The Bats in Churches project team would like to thank the church communities, ecologists, architects and buildings professionals, and the volunteers who have worked with or engaged with the project during its delivery phase. Additionally the team would like to thank the partner organisations: the Bat Conservation Trust, the Churches Conservation Trust, Church of England, Natural England and Historic England. Finally we would like to

thank the National Lottery Heritage Fund for its support, without which the project would not have been possible.

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Western Barbastelle (*Barbastella barbastellus*) Bat in Wales

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Daniel Hargreaves*; Vincent Wildlife Trust

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Current Status

Bat workers have long known that we have the elusive barbastelle *Barbastella barbastellus* bat in Wales (Figure 1), but what do we really know about its status and do we even really know its actual range in Wales?

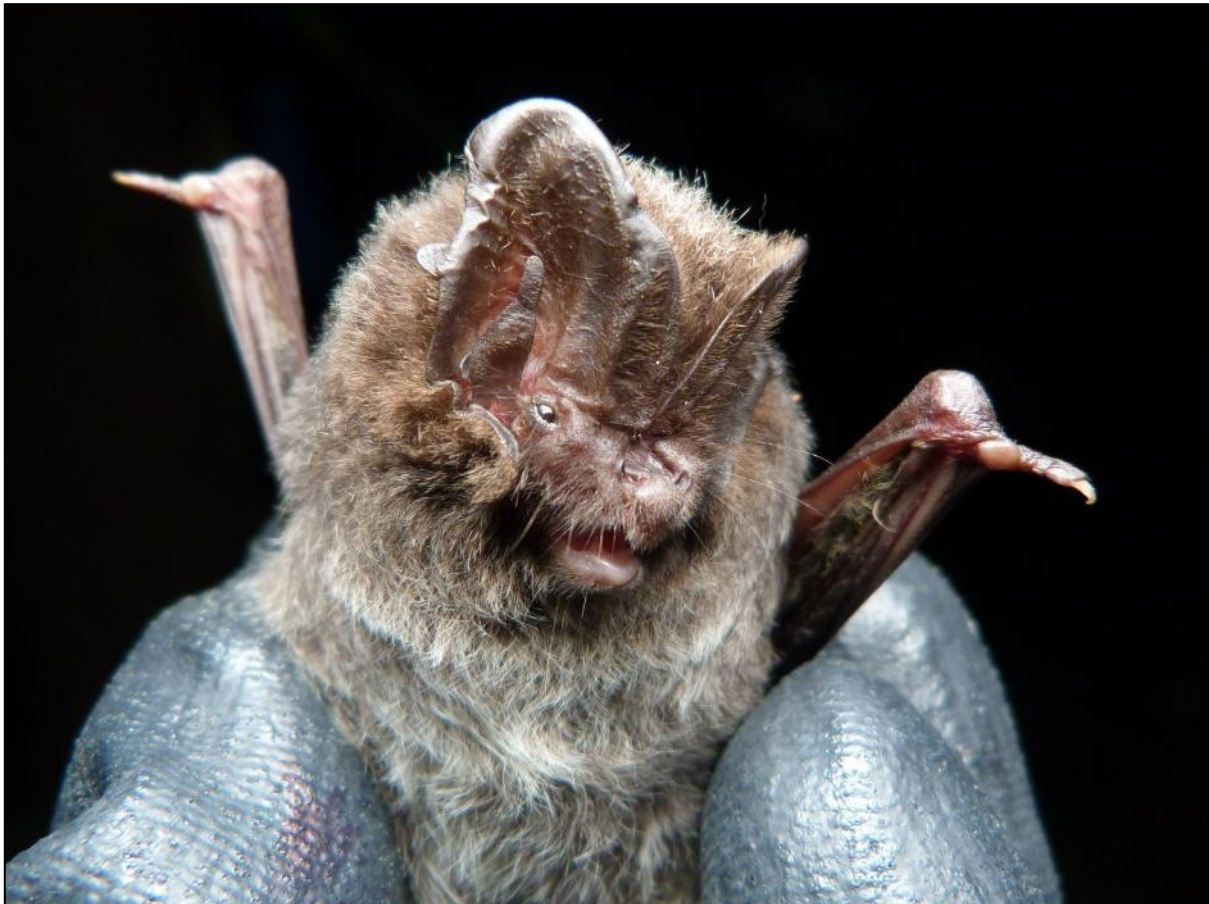


Figure 1: Adult barbastelle in the hand.

Figure 2 shows in red the accepted range of barbastelle bats from Mathews *et al.* (2018), and the green squares show records held by the Local Environmental Record Centres; these cover all record types, unsurprisingly the vast majority of records are detector records. (Reasons for some records falling outside the accepted range can be found within Mathews *et al.*, 2018.)

We can clearly see four distinct areas: Pembrokeshire, Monmouthshire/southern Powys, northern Powys and southern Gwynedd. However our knowledge of barbastelle varies significantly between areas.

roosting in relatively exposed locations results in barbastelles regularly roost switching, and this behaviour is seen throughout the winter. The benefit of surveying through the winter is that many species are less active and so the volume of data to analyse is reduced, with work being targeted towards identifying areas where barbastelle may be roosting. After initial data analysis, Microsoft Power BI was used to create activity 'heat maps' to guide future efforts (Figure 3).

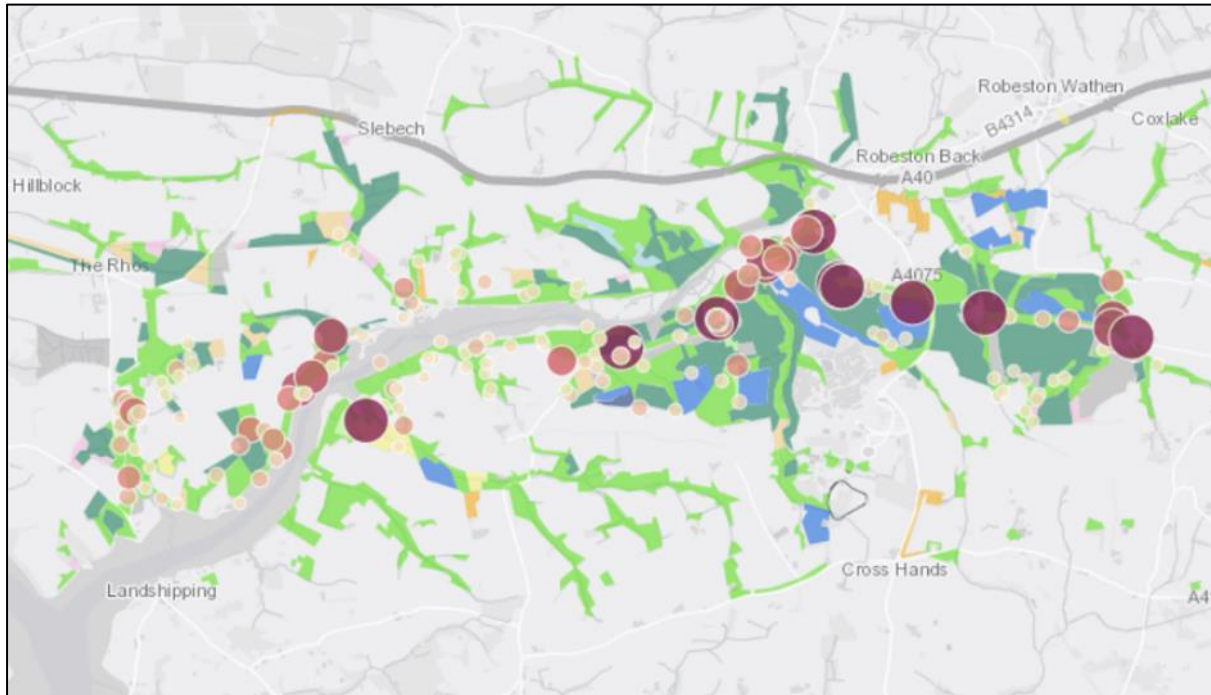


Figure 3: Microsoft Power BI map displaying detector records. The larger and darker the circles, the more activity was recorded.

Following this great success, achieved purely because of the time and dedication of a wonderful group of bat enthusiasts, in 2019 NRW funded and licenced a radio tracking project to identify roosts, foraging areas and commuting routes for the species. Additional summertime detector surveys were completed to inform the trapping efforts required. Six bats were captured and tracked under contract; the work was again supported by the bat group volunteers.

The study confirmed the presence of breeding barbastelles between Picton Park and Narbeth and identified 13 roosts in total within the woodlands. All roosts were located in trees, 11 of these were in oak (84%), heights of roosts ranged from 3m to 11m (average 7m); the selection was affected by the composition of the woods with oak being the dominant species. Seven (53%) of the roosts were found under plates of flaking bark, four in splits (30%) and one behind thick ivy.

In terms of population size, the study concluded that a minimum of 39 barbastelles were located from the roost counts and tracking data, though as adult females usually congregate together it is likely that most of the counted bats are adult females and making the presumption that juveniles were not yet volant and that equal number of males and females are born gives a likely minimum population size of 78 adult barbastelles within the study

area. Further information from this study, including behavioural and foraging insights can be seen in the full report, available from the NRW library¹ (Rush and Billington, 2020). It is hoped that this study will help to protect the species in the area and supported by additional information will form the basis for potential future site designations.



Figure 4: Juvenile barbastelles within a roost behind flaking bark of an oak tree, located during radiotracking in Eastern Cleddau; photograph taken once adults had all emerged.

The second most studied area in Wales is the south east, incorporating Monmouthshire, southern Powys and the eastern Brecon Beacons National Park. Again, most of our information comes from dedicated local bat workers in the area. In particular over recent years, Stephen Davidson has conducted in-depth studies of numerous woodland and swarming sites. Initially his work targeted the Llanthony Valley where his research indicated breeding colonies were likely present; more recently his focus has been on the Wye Valley region. Stephen regularly records barbastelle activity during his surveys there; the capture

¹ NRW library catalogue is available online at: <https://libcat.naturalresources.wales/folio/>

of barbastelles at swarming sites could indicate breeding in the area. He is also responsible for locating the first maternity roost for Bechstein's bat *Myotis bechsteinii* in Wales, and on the back of this NRW commissioned surveys of the Welsh Government Woodland Estate (which is managed by NRW). The work consisted of wide scale assessment of woodland blocks in the region to determine the potential for Bechstein's bat, followed up by trapping surveys of higher potential woodlands to gain a better understanding of the distribution of the species. The by-product of this work has also been the capture of barbastelles in multiple woodlands and the subsequent radio-tracking of several bats. Further information from this study can be seen in the full report, available from the NRW library¹ (Whitby and Binet, 2021).

The two northern areas within the species range in Wales are far less well understood and evidenced. Within southern Gwynedd, records are from detector surveys only, mainly undertaken for road schemes. There are no 'in the hand' or roost records for the species. Following their detection during surveys for one road scheme, considerable effort was spent trying to catch and track barbastelle, but to no avail. Snowdonia Mammal Group ran a four year mammal atlas project, which in part targeted woodlands using advanced trapping techniques (under licence from NRW), however once again no barbastelles were recorded.

One of the issues with gaining a better understanding of barbastelle in any area is that few records of bats in woodlands are generated unless they are part of a targeted project, unlike within built structures where consultancy works over time can generate many records and lead to reasonable representation. With this in mind, NRW recently commissioned detector surveys of woodland in the Dolgellau area specifically for barbastelle. Many records were generated, however none were of the target species.

It is a similar picture in northern Powys, with a low number of detector records within a wide range of dates. Within these two areas it is therefore unclear what the true status of the species is; are we missing breeding colonies?

What do we need to know?

The barbastelle bat is a vulnerable species, the fragility of roosting locations are at significant risk from unchecked forestry works; we risk losing colonies without ever knowing they existed. This is why we must keep driving forward to improve our knowledge of the species, and knowing where they occur is one of the first things we need to establish.

On a national level, modelling is a powerful tool to drive targeted efforts, as well as advise forestry works and development in the absence of 'solid evidence', which is proving elusive in the northern range areas. To aid future efforts, several models have been produced for a number of rarer bat species over the years, including barbastelle, an example of which is given in Figure 5. This clearly demonstrates the potential for the species to be widespread in Wales and provides focus for surveys to locate new colonies.

Within Pembrokeshire, we must continue to expand our knowledge of barbastelle. We are pleased that they will be the subject of a species-specific project within 'Natur am Byth!'. The Natur am Byth partnership is Wales' flagship Green Recovery project. Led by NRW, it unites nine environmental charities (including the Vincent Wildlife Trust and the Bat

Conservation Trust) to deliver the country's largest natural heritage and outreach programme to save species from extinction and reconnect people to nature. Similar to England's 'Back from the Brink' and Scotland's 'Species on the Edge', the project is funded by National Lottery Heritage Fund, with match funding secured from NRW and additional support from the Welsh Government.

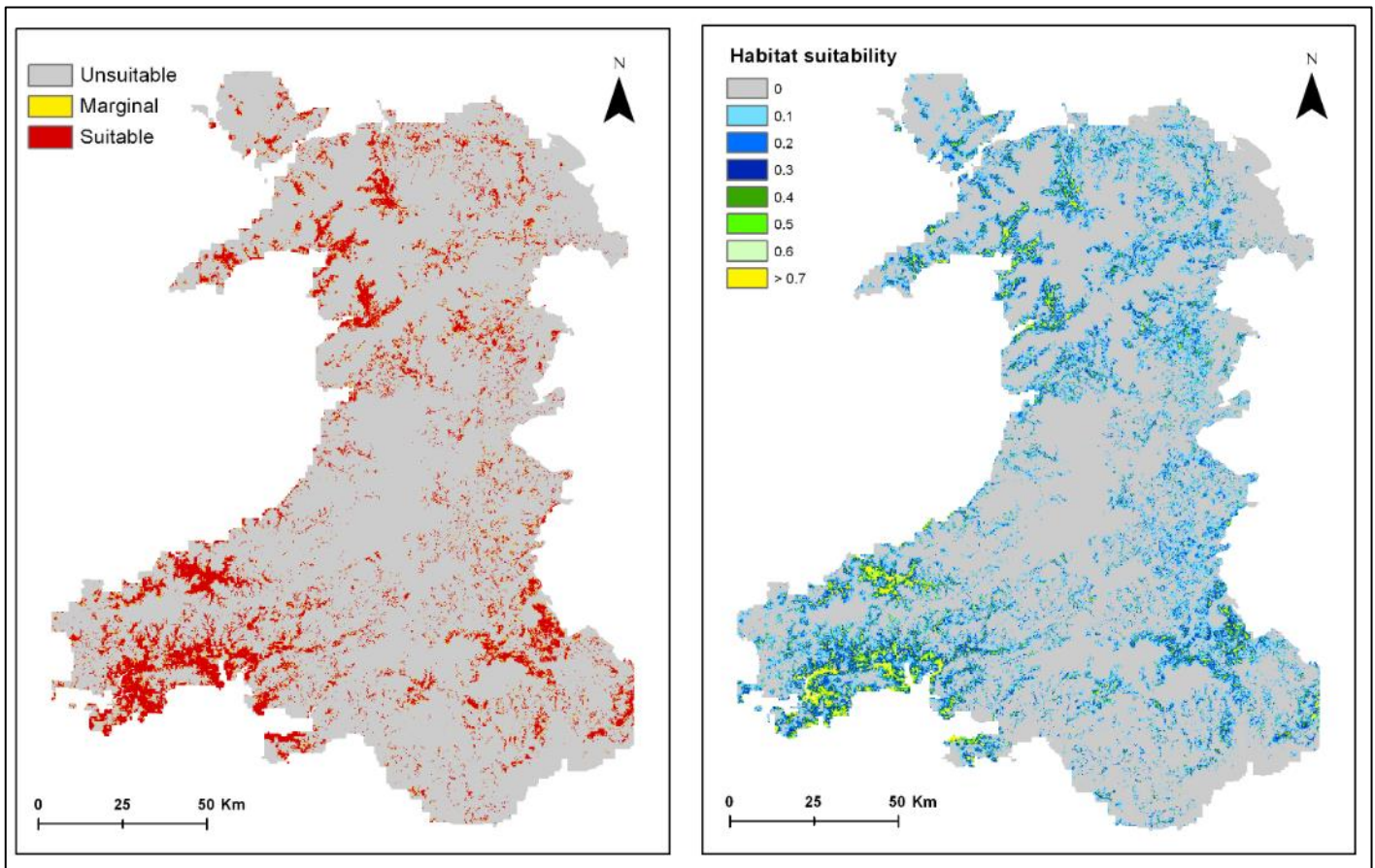


Figure 5: Maxent modelling output habitat suitability maps for barbastelle in Wales. The reclassified map, on the left, shows unsuitable areas in grey, marginal habitats in yellow and suitable areas in red. The continuous map, on the right, shows habitat suitability ranging from unsuitable (zero suitability) in grey to highly suitable (suitability > 0.7) in yellow. (Razgour, 2013).

The Vincent Wildlife Trust is a core partner in Natur am Byth!, taking the lead in the conservation efforts for barbastelle bats in Pembrokeshire. Using techniques developed through a recent University of Sussex PhD by Kieran O'Malley, the project aims to train volunteers from local communities in acoustic surveying to help us identify woodlands used by important maternity colonies. Engagement combined with spatial modelling techniques will locate key places for action on the ground, help us highlight important areas for appropriate woodland management, find opportunities to enhance roosting habitat and improve connectivity in the wider landscape. Appropriate woodland management and habitat enhancement work will also benefit other woodland species such as hazel dormouse *Muscardinus avellanarius*, willow tit *Poecile montanus* and saproxylic invertebrates. The prospect of combining science, volunteers and on the ground management holds great

potential to further the conservation of the barbastelle in Pembrokeshire and will form a project model to guide works in other areas of Wales as part of its legacy.

Given that Wales only has one designated area for barbastelle (a SSSI within the North Pembrokeshire Woodlands SAC), it is hoped that information from Natur am Byth!, combined with further intensive studies (as required) will provide sufficient evidence to designate new areas as SSSIs to protect barbastelle colonies in the future.

Within the south-east, Stephen Davidson will continue his research work which produces more evidence each year which helps determine the regional status of the species.

While defining the northern distributions remains problematic, a new two-year Bat Conservation Trust project 'Gobaith Coetir – Woodland Hope' aims to help some of our rarest bats and most precious woodlands in North Wales, with a special focus on Celtic rainforests and the lesser horseshoe bat *Rhinolophus hipposideros*. This project is funded by the Nature Networks Fund, via the National Lottery Heritage Fund, on behalf of the Welsh Government. 'Gobaith Coetir – Woodland Hope' will use AudioMoth detectors, involve and upskill the local community in citizen science, work with local partners and make it possible to monitor woodland bats in innovative and collaborative ways. This project will then advise on woodland recovery to help bring them back into healthy condition. While the focus may be lesser horseshoe bats, it will result in many new records and benefits for all woodland bat species, and with luck, more information about barbastelles in the area may be gleaned.

Summary

There are many other questions to be answered regarding barbastelles in Wales, including on their behaviour and ecology. However in the short term, our emphasis remains quite simple, where are they and how do we ensure they are appropriately protected? While these basic requirements may in truth be extremely challenging, the numerous dedicated bat workers across Wales attempting to seek answers and work collaboratively with other individuals, groups and organisations will no doubt continue to rise to this challenge.

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