

Devon Bat Survey 2016 – 2020

Final Report



The Devon Greater Horseshoe Bat Project ran from October 2015 until January 2021. This report provides a summary of the aims, achievements and recommendations from the Devon Bat Survey.



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1. Summary of Key Findings from the Devon Bat Survey (DBS) 2016-2020

- DBS has provided firm evidence of the importance of Devon for bats. The county is a stronghold for many of the UK's most threatened bat species and we hope that the data gathered through this fantastic citizen science project can help inform and support bat conservation into the future.
- DBS ran from 2016-2020 using 20 SM4 detectors, supported by 20 host centres each year
- Between 2016 and 2020, 2553 surveys were conducted through DBS, within 1387 monad survey squares (1km^2) across Devon (almost 20% of Devon).
- DBS became more popular each year. Almost 60% of volunteers in the final year had taken part before and increasing numbers of survey squares were surveyed each year.
- 3.8 million sound recordings were generated over the course of the project (over 2 million of these were found to be bat recordings).
- Over the course of the DBS we have identified at least 12 of the 16 known bat species found in Devon (the remaining 4 were likely to have been detected but difficult to verify through sound analysis alone).
- On average, 54% of surveys recorded greater horseshoe bats on 37% of 1km^2 squares surveyed over the course of DBS.
- DBS has increased the number of 1km^2 locations in Devon known to hold greater horseshoe bats from 576 to 975 in the course of just 5 years.
- Barbastelle bats were recorded at 59% of monad squares that were surveyed and 55% of individual surveys over the course of DBS.
- DBS increased the known locations where barbastelle have been found from 132 1km^2 squares to 890. This is a remarkable almost 800% increase in data and strongly suggests that barbastelle was under-recorded previously across the county.
- DBS has increased the known 1km^2 locations where lesser horseshoe bats (LHB) are found from 836 to 1344. LHB were recorded in 40% of surveys undertaken and 52% of survey squares surveyed.
- Devon's rarer bat species were recorded at surprisingly high rates in urban areas (Torbay, Plymouth and Exeter) indicating that urban environments are important for bat conservation and city dwellers can help improve the outlook for bat conservation in Devon as much as rural dwellers.



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2. Introduction

Devon Bat Survey (DBS) was a large-scale citizen science project (one of the largest of its kind in south-west England) which aimed to engage hundreds of volunteers in collecting bat data throughout the course of the Devon Greater Horseshoe Bat Project. As well as raising awareness of greater horseshoe bats (GHB) in Devon, it saw the collection of a huge amount of vital bat survey data. The survey data adds to our existing knowledge about GHB in Devon, as well as collecting data about all other bat species in the county.

The methodology was based upon the pioneering work of the Norfolk Bat Survey, undertaken by Stuart Newson and his team at the British Trust for Ornithology (BTO), without whom DBS could not have been run. A key difference between the two approaches was that the Devon Bat Survey aimed to use a high volume of inexperienced volunteers rather than fewer experienced volunteers, as was undertaken in Norfolk. This reflected the aim of the DBS to engage and inspire as many people across the county as possible as well as gather important and useful data.

This report aims to summarise the key findings from the 2016 – 2020 survey seasons with particular reference to greater horseshoe bats, lesser horseshoe bats and barbastelle bats which are each listed under Annex II of the Habitats Directive (Bechstein's, also listed under Annex II of the Habitats Directive, has not been focused on within this report due to the difficulties of accurately identifying it through acoustic data). This report also makes future recommendations for how to continue this highly popular and successful citizen science project into the future.

N.B. Due to time constraints, and the huge amount of data produced through the DBS, species other than the 3 focused on in this report will be analysed separately and the results shared through the Devon Wildlife Trust website at a later date.

Aims of the survey

- Increase our understanding of the distribution of bats (with a focus on GHBs) across Devon
- Increase people's awareness of bats in Devon by taking part in the survey and better valuing local spaces for bats
- Improve understanding of bats in Devon to inform land management advice, planning decisions and future research directions

Scope of project area

DBS covered the whole of Devon. A 1km grid square map (each 1km² referred to as a monad) was created to allow a distribution of survey effort across the county. Participants could then select one of these grid squares to survey per year, ensuring that as many separate grid squares were selected for survey as possible each survey season.



Survey Timings

The DBS operated throughout the course of the Devon Greater Horseshoe Bat Project (DGHBP) from 2016 – 2020.

2016 The first survey season aimed to test the methodology. It ran for the last 11 weeks of the season from August to the end of October using 10 bat detectors at 10 Monitoring Centre locations.

2017-19 20 detectors hosted by 20 Monitoring Centres from April – October.

2020 The survey was planned to run from April – September (to allow data processing time for the original project end date of October). With Covid-19 restrictions this was not possible. However between August-October, 11 Monitoring Centres were able to support the survey.

3. Methodology

For full details refer to the ‘How to run Devon Bat Survey’ document (available from Devon Wildlife Trust).

The survey methodology was chosen to balance ease of use with robust data collection. As one of the main aims of the DBS was engagement with the public, only limited control of where detectors were placed could be exercised. This seemed like it could be problematic at the start, but due to the sheer numbers taking part, the unpredictable nature of where the detectors were placed added to the interest of the final results (e.g. high numbers of bat calls found in urban areas).

An overview of the survey methodology is as follows:

- Using an online booking system (developed by the BTO), a volunteer borrowed an SM4 bat detector for 4-6 days (3-5 nights) from a Monitoring Centre in Devon (survey length varied depending on Monitoring centre opening times). Volunteers were asked to make one booking only to allow as many people as possible to take part in the survey.
- Members of the DGHBP project team were able to verify bookings online and were on hand to answer queries from emails and phone calls throughout the survey season (often multiple queries per day).
- Monitoring Centres were public-facing locations (e.g. Cricklepit Mill in Exeter, Watermark Centre Ivybridge; see Appendix 8 for full list of participating centres) that were happy to act as pick up and drop off points for participants, who had been approached by the project and were happy to take part.
- Once collected by a volunteer, the detector was set up in the 1km grid square that they had chosen and been approved by DGHBP staff from an online map. The detector was set up in one location for the entire survey to record any detected bats calls onto an SD card (if the volunteer did not own the land they had to seek signed permission from the owner).

- The volunteer returned the detector to the monitoring centre, ready for the next volunteer to collect on the following day.
- The SD card was posted back to the DGHBP team for uploading and analysis.
- Based on the results of auto ID software (developed by the BTO), a report was sent (usually via email) to the volunteer detailing:
 - the species of bats found
 - number of passes
 - information about the different species
- Verified data on all bat species was passed on to the Devon Biodiversity Records Centre for future use and storage.

The information collected aids understanding of where GHB and other species of bats live across Devon. It aimed to result in finding new roosts and ensure that work is focused in the right areas.

Monitoring Centres

Centres were spread as evenly as possible across the county, within the constraints of finding willing venues to take part. They were a mixture of garden centres, libraries, museums and town halls. Without their goodwill and support it would not have been possible to run DBS.

Equipment

20 SM4 detectors were used for the DBS survey. Initially the plan was to use 40 Anabat express detectors for DBS due to their lower cost. However, it became clear that while they were really useful for some situations, they would not be suitable for the DBS:

- Large scale use of them in DBS would have resulted in a vast amount of data for analysis
- No automatic identification was possible at the time of setup and therefore all the data had to be manually analysed
- The DGHBP team did not have capacity to analyse the data, even with volunteer help
- Anabats are not full spectrum so do not provide as much information

Therefore 20 SM4s were deemed to be the optimum choice:

- They are full spectrum
- Data can be run through automatic identification software with the option for manual verification at a later date
- They were considered easier to use if volunteers were unable to set up the detector correctly e.g. lack of a GPS read was not an issue and incorrect location data could be corrected after the survey.

Survey Locations

Any monad squares within the county (and covering a small area of the DGHBP project area over the border into Cornwall) could be booked by volunteers each year. After the first year, ‘priority squares’ were identified on the online booking system to indicate to participants where no data had yet been collected, or there was an existing lack of GHB data held for that area.

Further details



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The 'How to run Devon Bat Survey' guide (available from DWT) covers the following details:

- Booking system – how does it work
- Monitoring Centres
- The Equipment
- SM4s – servicing, maintenance, battery requirements
- Administration and support for volunteers
- Volunteer information
- Data – uploading, reports, getting data to DBCR, results maps
- Appendices include:
 - Information for website
 - List of documents available
 - DBS Kit and Time Costs

4. Results

Survey effort and volunteer participation

As can be seen from Figure 1, survey effort was generally focused around more densely populated areas, and very few surveys were conducted on the high moor of Dartmoor, probably due to access issues and low population density. Despite the unpredictable nature of the survey in terms of where people chose to place detectors, over the course of the 5 years almost 20% of the available monad squares were surveyed, and these were well distributed throughout the county.

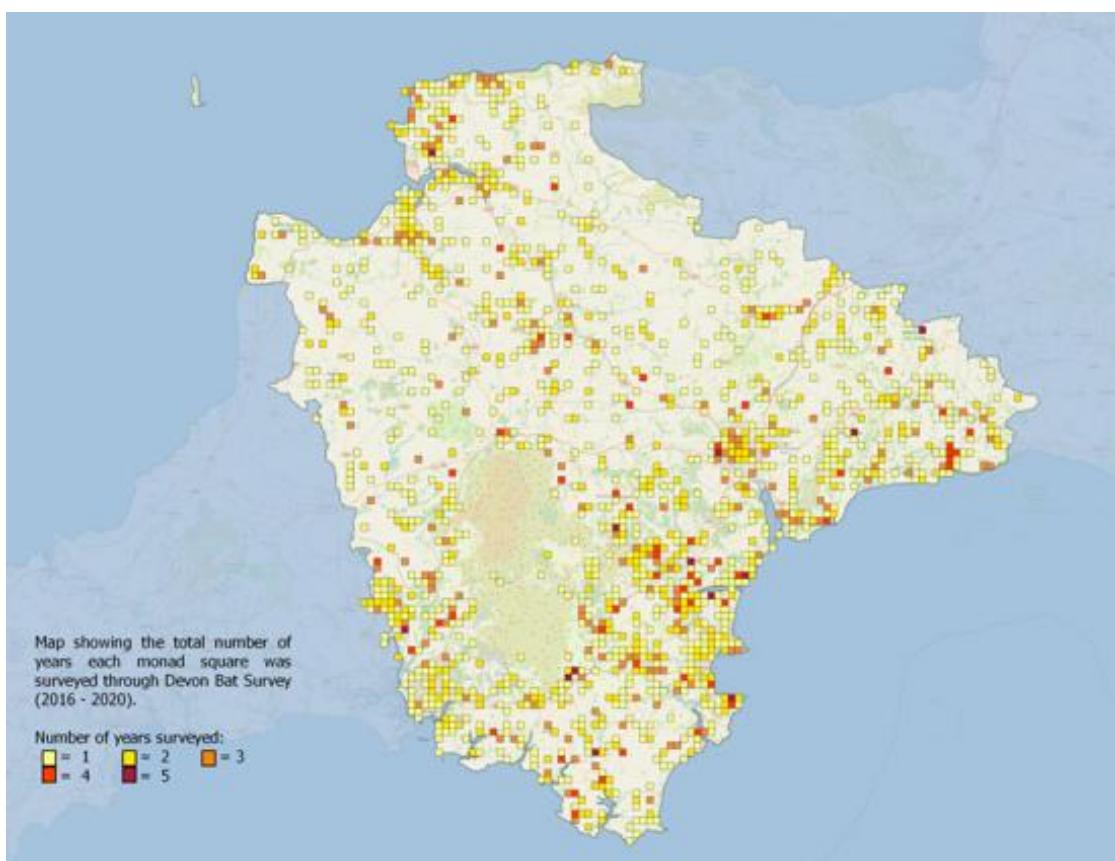


Figure 1. Monad survey squares covered through Devon Bat Survey (2016 – 2020) some squares were surveyed multiple times, with the majority just once or twice.

Between 2016 and 2020, 2,553 surveys were conducted through DBS, within 1,387 survey squares across Devon.

Table 1. Total Squares and Surveys carried out through Devon Bat Survey each year

Year	Duration in Months	Detectors	Monad Squares	Surveys	Cumulative total surveys	% total surveys
2016	3	10	129	154	154	6%
2017	7	20	630	706	860	27%
2018	7	20	646	722	1582	28%
2019	7	20	684	747	2329	29%
2020	3	11 full (+ 9 ad-hoc*)	214	224	2553	9%

*Due to the pandemic many venues were shut during the 2020 survey season, however 11 detectors were loaned out in the normal way between August and October in 2020. The 2020 survey season also involved a small number of dedicated volunteers deploying the 9 other detectors for 3 nights per site – these detectors were not used continuously but did gather important additional data for a number of new survey squares.

The number of participants gradually increased each year (apart from 2020 which was a shortened survey due to Covid-19 restrictions). In 2016, 145 different households borrowed one of 10 detectors between August and October. From 2017 to 2019 20 detectors were available from April – October each year and the number of surveyors grew each year from 636 in 2017, to 668 in 2018, to 675 in 2019. In 2020 192 different households borrowed 1 of the 11 detectors available during the August – October survey period meaning that, based on detectors and survey slots available, it was the most popular year so far. Devon Bat Survey therefore became more popular each year it ran.

Table 2. How many volunteers were new and how many had taken part previously each year (based on subset of 500 volunteers)?

Year	Total Surveyors	Total surveyors who had taken part previously	Percentage taken part previously	Percentage new
2016	42	All new	All new	All new
2017	189	12	6%	94%
2018	223	66	30%	70%
2019	212	125	59%	41%

Based on a subset of data (2016 – 2019) of 500 participants, the number of volunteers who returned to Devon Bat Survey increased from 6% in 2017, to 59% in 2019. This indicates that it was becoming a popular annual activity for participants, and was likely to remain popular into the future if the survey was continued. It should be noted that from feedback forms and communication with volunteers, the fact that centres became fully booked very quickly and that only 1 survey was allowed per monad square per year, led to restricted participation; more people would take part each year if Devon Bat Survey was expanded to either allow more surveys in each square or with more detectors available.

See Appendix 7 for an example of the report sent to participants.



Here are a few quotes from participants from the 2019 Devon Bat Survey:

"Wonderful educational experience for our family. The children loved taking part! Easy to understand process and instructions"

"Third year doing this. Now have all my family and place of work involved. Love taking part and feeling my little input could be of use"

"We have really enjoyed this experience. The kids have loved staying up to see the bats come out at dusk"

Survey centres

Generally, the most popular centres were those nearest to major towns and cities – Cricklepit Mill in Exeter and all centres that were distributed along the A30 and A38 were booked up very quickly each year. During the smaller scale survey of 2020, the majority of detectors were booked within 2 weeks of bookings opening, when only 8 of the 20 detectors were available and a waiting list had to be created to accommodate for individuals who had missed out on booking a detector.



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Overview of bat data

3.8 million sound recordings were generated over the course of the project – of these, 2.3 million are considered likely to be bats based on the automatic identification software provided by Stuart Newson and his team at the BTO. Of these, the following recordings have been identified as each species or species group through the automatic identification software. All automatically identified greater horseshoe, lesser horseshoe and barbastelle bat recordings are manually verified each year before being submitted to Devon Biodiversity Records Centre - all other species are in the process of being verified.

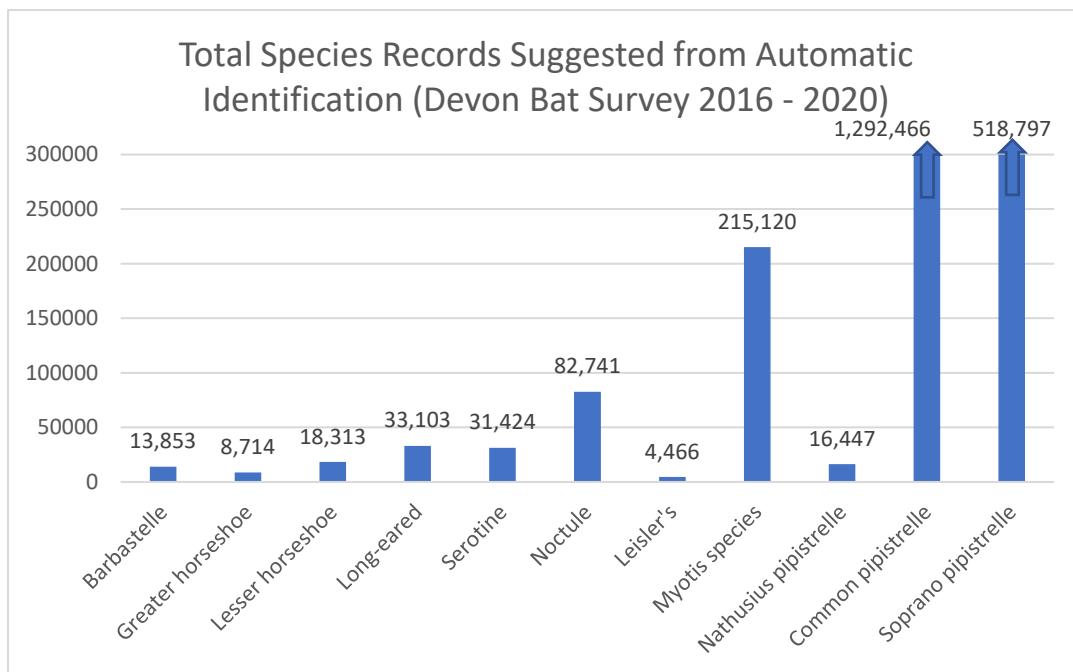


Figure 2. Total suggested species recordings (based on automatic identification software) generated through Devon Bat Survey from 2016 – 2020.

Based on the automatic identification data, common pipistrelle is estimated to be found in over 94% of monad squares during the course of DBS, making it the most commonly found bat species in the county. The least common species found was Leisler's bat which is estimated to be present in just under 5% of monad squares. Over the course of the Devon Bat Survey we have identified 12 of the 16 known bat species found in Devon. The only species which we have not identified to species level yet are grey long-eared bat, Bechstein's bat, Whiskered bat and Brandt's bat. It is likely that these species were detected, but they are very difficult to identify by call alone, usually requiring examination in the hand to identify confidently to species level.

Over the course of early 2021, further verification of bat species and their distribution will be completed and added as appendices to this report.



What does Devon Bat Survey tell us about 3 key species of bats in Devon?

In the following sections of the report, greater horseshoe bat, lesser horseshoe bat and barbastelle bat results are looked at in more detail. Due to time constraints with this phase of the bat survey, it is outside the scope of this report to look at all species of bat recorded through the survey in this level of detail. We do hope however that this work can be completed at a later date and added as an appendix to this report.

Results are generally represented as tetrad (2km² survey square) data or heatmaps in this report. This is in-line with our service level agreement with the Devon Biodiversity Records Centre (DBRC). Monad (1km² survey square) locations of bat records can be accessed through contacting DBRC.

Greater horseshoe bats

Greater horseshoe bats were the key focus of the efforts of the Devon Bat Survey and the following results show the depth and breadth of new information obtained through the project.

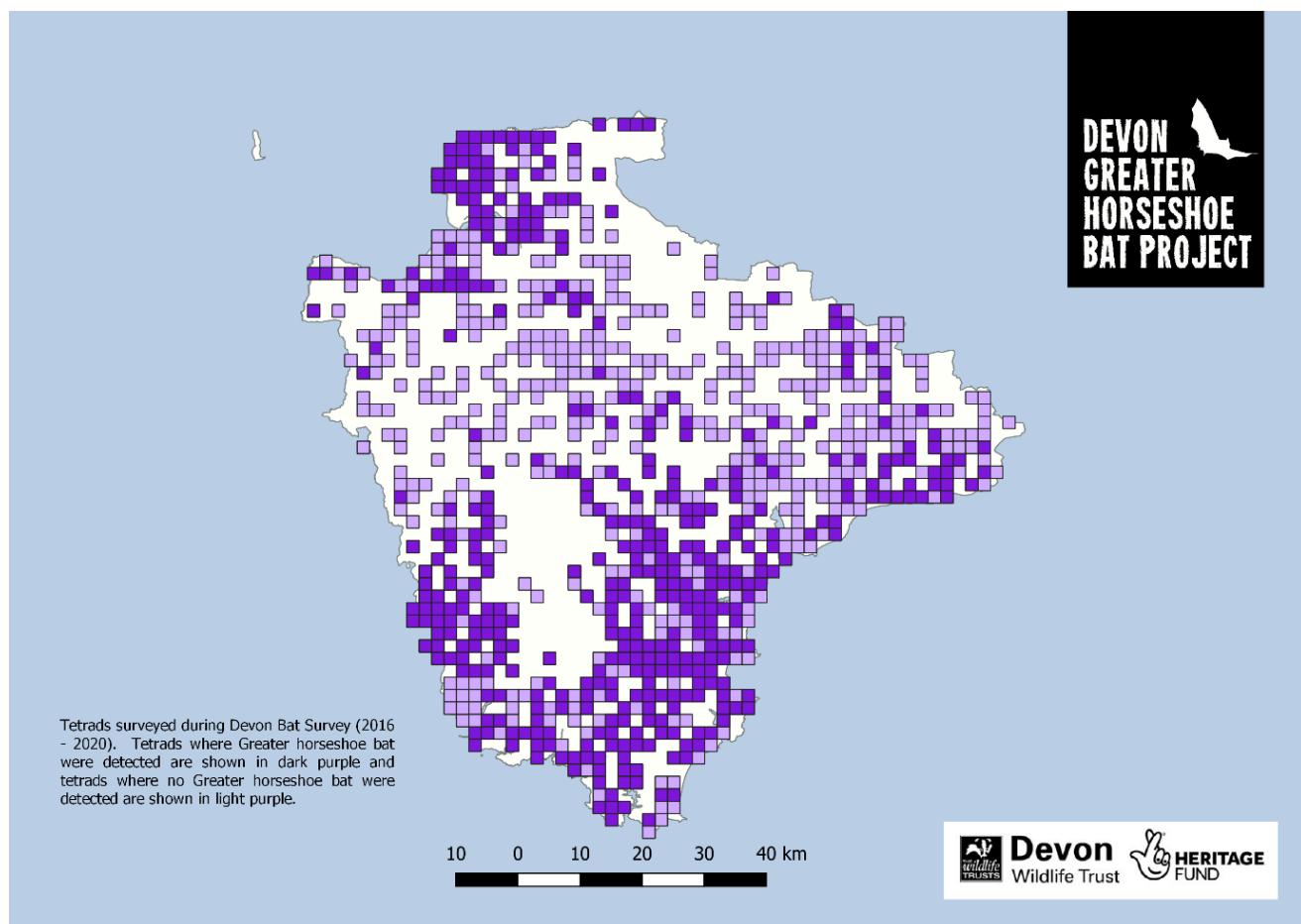


Figure 3. All tetrads surveyed in 2016-2020. Dark purple tetrads represent where GHBs were detected and light purple tetrads show where they were not.

Table 3. Frequency greater horseshoe bats were detected each year

Year	Total Monads surveyed / year	Total Monads with GHB records/year	% Monads with GHB
2016*	129	63	49
2017	630	230	37
2018	646	270	42
2019	684	216	32
2020*	214	52	24

*2016 detector locations were mainly within core sustenance zones and so a higher proportion would be expected.

On average, 54% of surveys recorded greater horseshoe bats on 37% of monads surveyed over the course of DBS. Although GHB activity was found throughout most of the county, there were areas where activity appeared to be much lower (in particular the central band of Devon north of Dartmoor). Even accounting for a lower survey effort in this region, it would appear that this is likely to be correctly identifying an area where GHB activity is much less common, with the exception of the Taw Valley. From the limited data in that area, Taw valley looks like it could be an important link between populations in the north and south of the county and warrants further focus in the future.

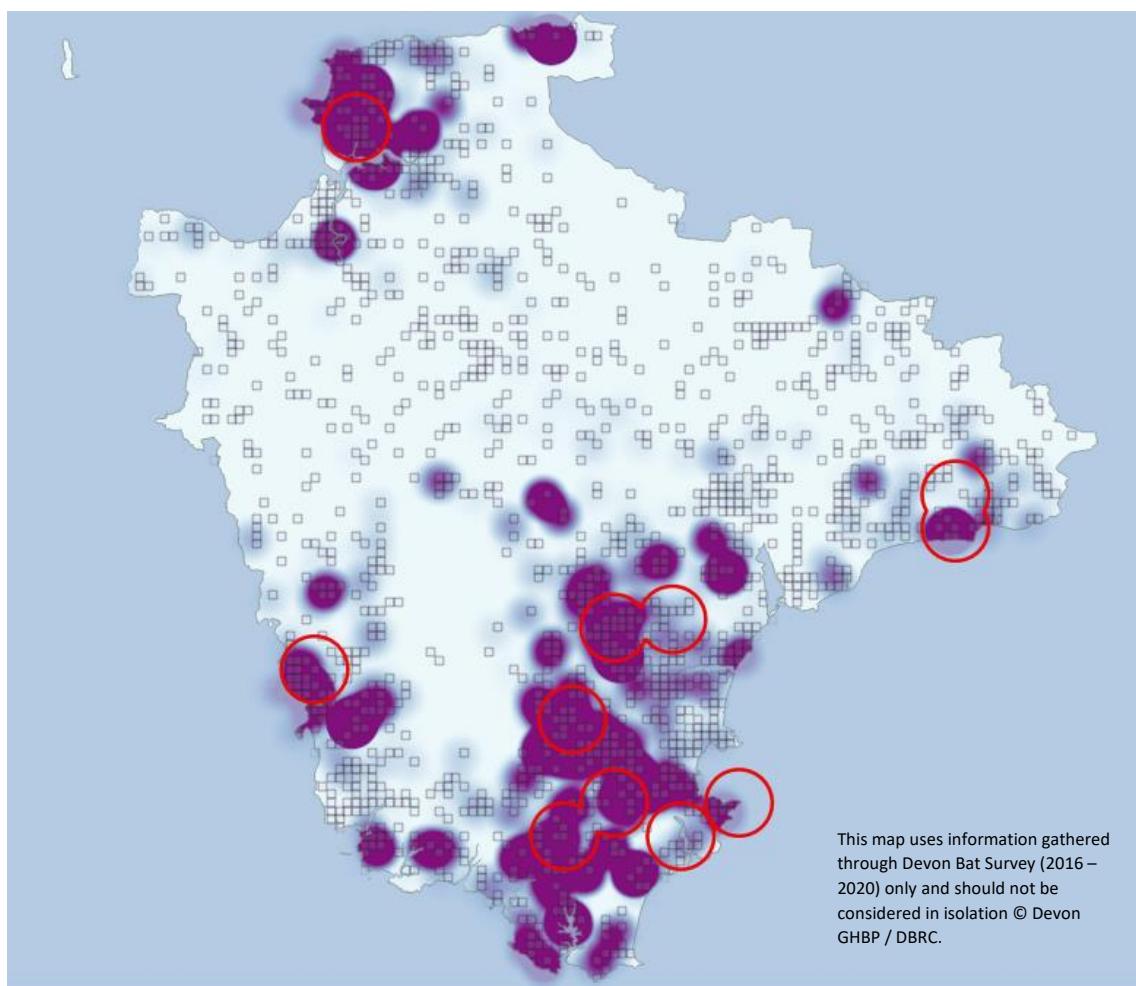


Figure 4. Heatmap of all greater horseshoe bat records gathered through Devon Bat Survey (2016 – 2020) with monad survey square effort and core roost zones shown as red circles.

The heatmap in figure 4 clearly shows hotspots of activity in the South Hams, around Braunton, Gunnislake and the eastern fringes of Dartmoor stretching towards the Exe Estuary. South-east

Devon also has areas of high activity, but not to the same extent as that found further to the south of the county.

Caution should be used however when interpreting these results. Survey effort could for example be skewed towards gardens and built-up locations in some areas, such as East and Mid-Devon, giving an illusion of lower GHB activity in these areas. Through gathering high volumes of data each year, these natural variations in survey effort are likely to become less important in interpreting the results.

Timings and proximity to roosts

Greater horseshoe bats are known to emerge from their roosts approximately 10 minutes after sunset and head out to their foraging and hunting grounds immediately after this. Using this information we decided to interrogate the data on GHB passes to understand where high numbers of passes were occurring within 30 minutes of sunset (so within approximately 20 minutes of GHBs emerging). This information can then help us identify potential new roost sites and further identify locations where land managers and communities can focus GHB conservation efforts in the future.

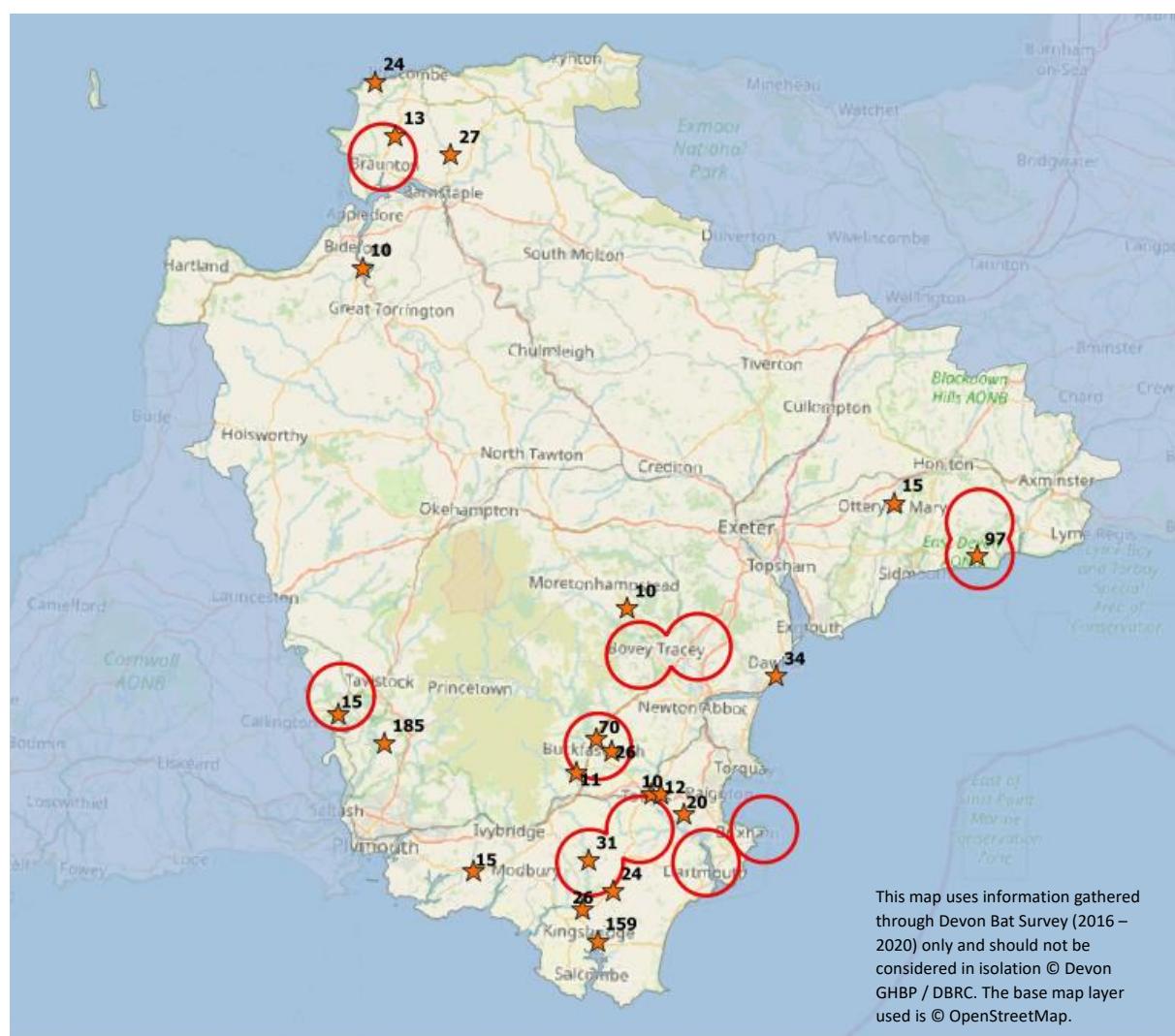


Figure 5. Devon Bat Survey GHB 2017 – 2019 data: all sites where GHB were detected within 30 minutes of sunset or sunrise, suggesting a day roost could be present nearby (only sites with >10 passes by GHB were detected over the 3-5 night survey period are shown). Red circles represent DGHBP project areas/ major GHB maternity roosts.

A number of sites warranting further investigation have been highlighted through this process. In particular, sites near Kingsbridge, Buckland and Dawlish are not thought to be within 20 minutes commuting distance of a known maternity roost, but show far higher numbers of passes than expected if other unknown roosts were not nearby. Further investigations of these sites should be conducted to determine where these bats might be coming from and how they link with the wider population.

Locations with high passes of greater horseshoe bats

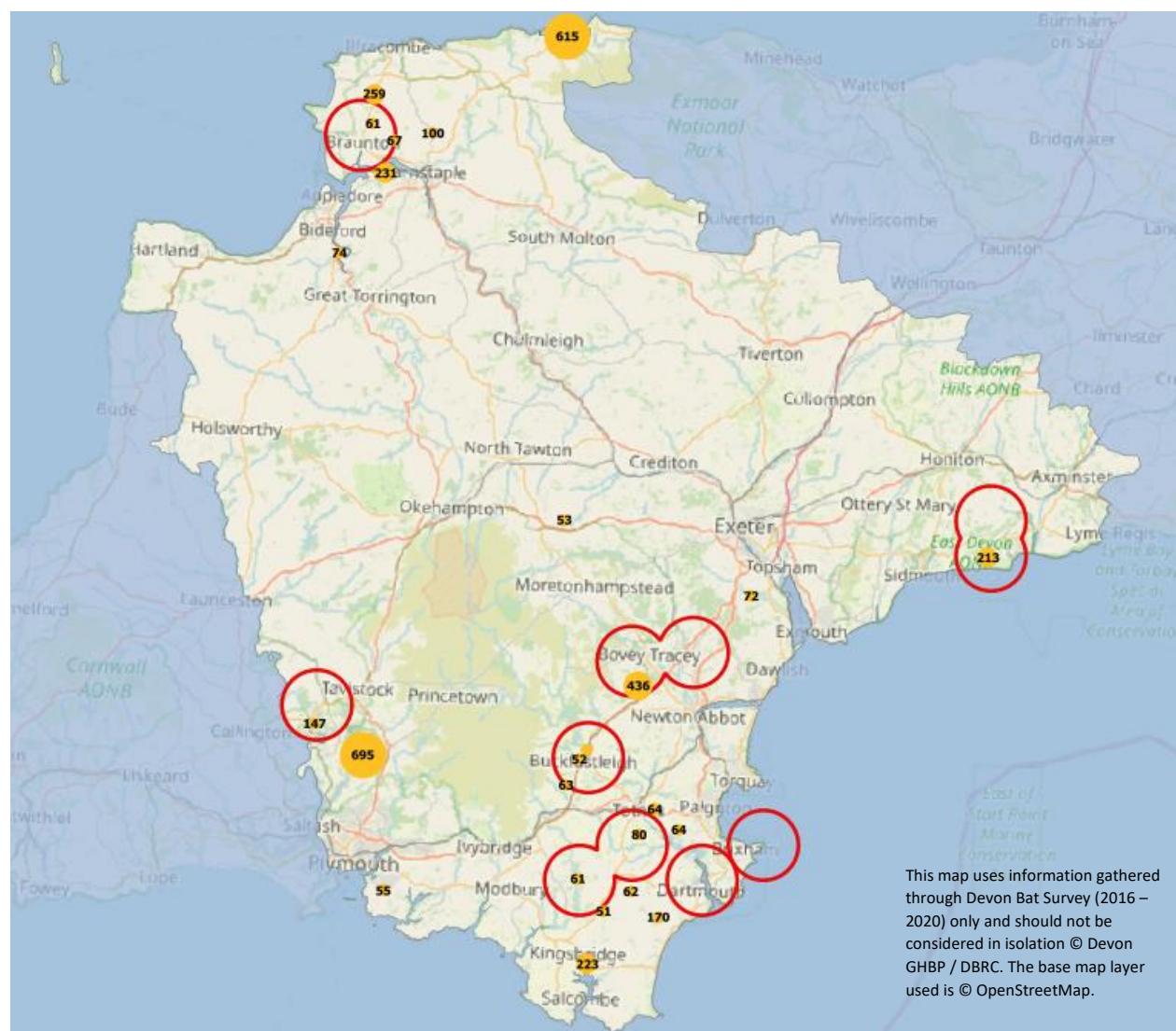


Figure 6. Total greater horseshoe passes at each high pass site (high passes = 50+ over the survey period between 2016 – 2020). Red circles represent DGHBP project areas/ major GHB maternity roosts.



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Table 4. Sites with the highest number of greater horseshoe bat passes per year

Year	Total Passes	Survey start date	Survey Length (in nights)	Grid Reference	Comments from survey sheets
2016	52	28/08/2020	3	SX7366	N/A
2017	213	24/08/2017	3	SY2089	Sited in the garden of a bungalow, next to farmland – grass.
2018	695	04/05/2018	3	SX4866	In a loft.
2018	223	19/09/2018	3	SX7442	In entrance to crypt.
2019	231	26/08/2019	4	SS5133	Separated from [redacted] inlet by 10 yards.
2020	436	14/10/2020	3	SX8074	On edge of woodland plantation overlooking horse field.

Particularly high passes found on the north coast of the county and around Buckland warrant further investigation, as well as a surprising hotspot between Okehampton and Exeter, not apparently close to any large maternity roost sites. These data along with the post-sunset GHB data should be taken together to further investigate these interesting hotspots of activity.



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Improved understanding of where GHBs are in Devon

Over the course of the project, DBS has contributed 822 new locations for greater horseshoe bat to Devon Biodiversity Records Centre. Before Devon Bat Survey, DBRC held data on greater horseshoe bat in 576 monad squares across Devon. By the end of Devon Bat Survey, this had increased to 975. This represents a remarkable increase in the data for Devon and indicates the real benefit of using a citizen science methodology in order to greatly increase our understanding of bat populations, outside of the already well documented benefits of increased awareness of local wildlife through citizen science projects.

Comparison of GHB records held by DBRC and those found by DBS

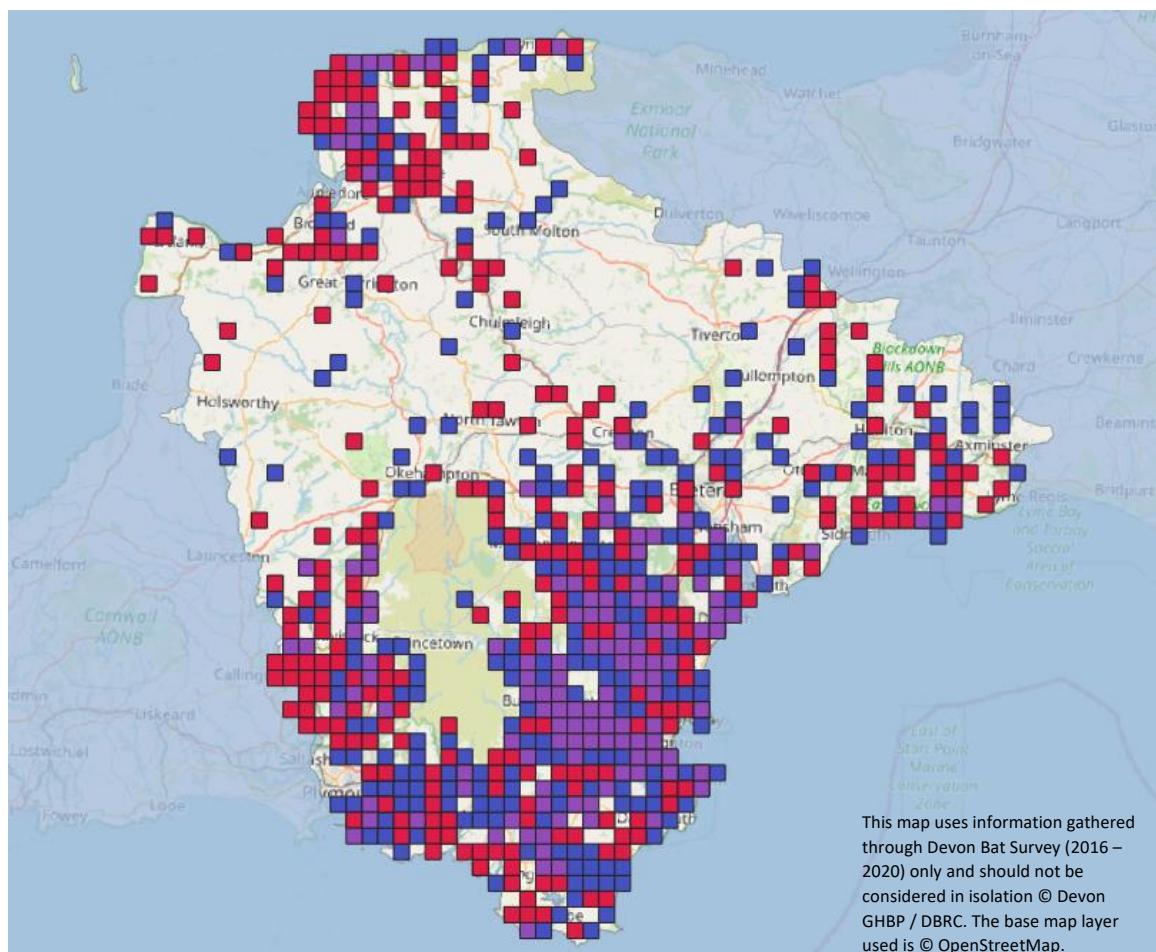


Figure 7. Tetrads where GHB records were already held by DBRC (blue), new data gathered through DBS (red) and tetrads with GHB held by DBRC but updated with new records through DBS (purple). Data from DBRC from 1948 – 2020, DBS data from 2016 – 2020.

DBS has contributed 399 new monad squares for greater horseshoe bat, to the 576 monad squares previously held by DBRC. In addition, DBS has provided new records for 185 monad squares where DBRC held historic data for this species. This is all the more remarkable given that DBRC have a data set representing over 70 years of recording and DBS represents just 5 survey seasons of survey effort.

Habitat associations with GHBs

Along with species, survey data and pass information, Devon Bat Survey has gathered habitat information for each location surveyed. Initial graphs of habitat in relation to GHB sites from DBS 2019 are presented below. Further analysis of habitat association was considered to be outside of the time constraints for the project.

In the future though, continuing to gather this information will help improve our understanding of the habitats which GHBs and other species are most likely to be associated with.

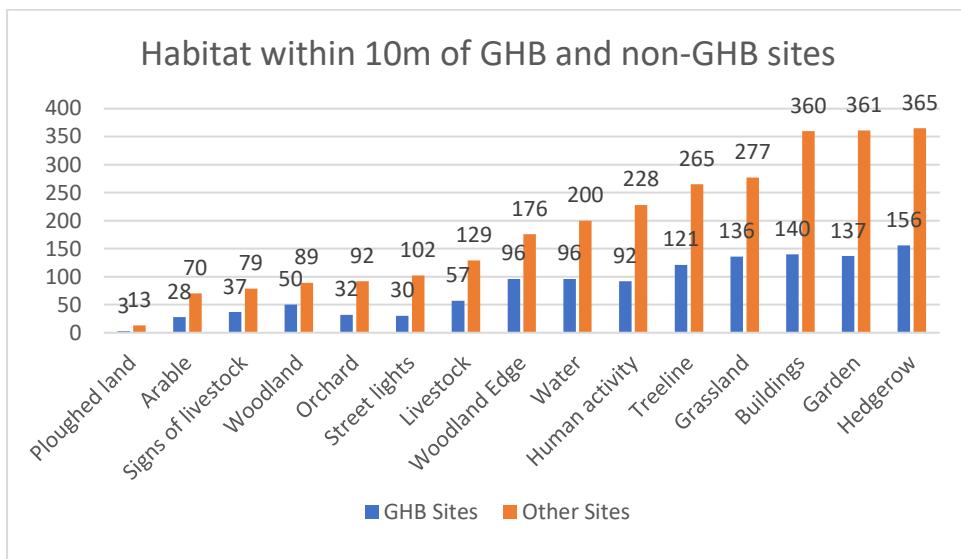


Figure 8. Habitat within 10m of sites during the 2019 Devon Bat Survey

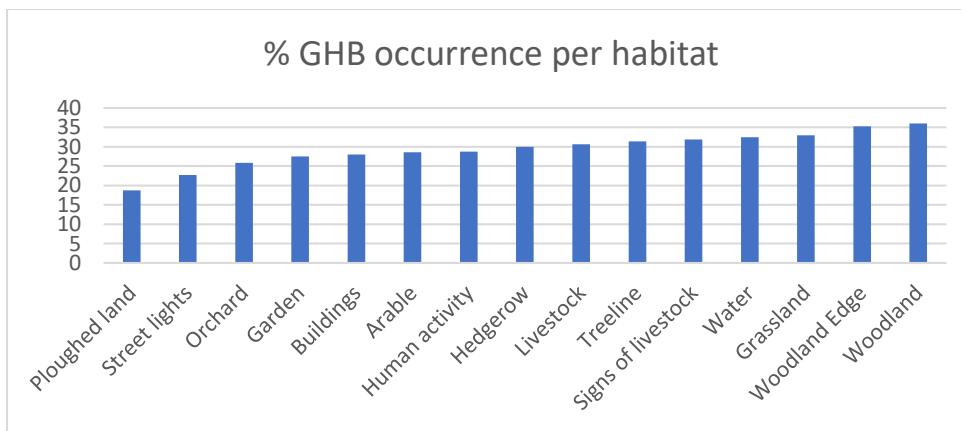


Figure 9. Habitat within 10m of sites where GHB were detected during the 2019 Devon Bat Survey

Although these graphs only represent a small sub-set of the data received for this information it does throw up some interesting results to consider and further explore. For instance, GHBs appear to be most strongly correlated with woodland and woodland edge, further supporting the planting of small areas of woodland in and around grassland areas (the next most strongly correlated habitat). This area of research should form a greater focus in future DBS survey and analysis efforts.

Key findings and future recommendations for GHB research

- Taw Valley: is the Taw valley an important link between north and south Devon populations of GHB? A future focus on this area for surveying would be useful along with engagement with landowners.
- Exminster marshes/Dawlish: high pass numbers here suggest a potential roost site towards Dawlish, with important foraging grounds around the Exminster marshes. RSPB have been involved with the project and have been investigating these records, but future work and engagement with landowners in the area should continue.
- Whiddon Down area: high passes of GHBs were recorded here, but not within 30 minutes of sunset, indicating there could be further activity nearby and future ‘priority squares’ should be allocated in this area. Records of roosts in the surrounding area should be re-visited where possible to see if populations are breeding here. This population may be particularly important as a link between north and south Devon populations of GHBs and associated with the Taw Valley.
- Between Bideford and Great Torrington there were 10 passes recorded close to sunset and 74 overall. This could be an important commuting route for the population near to Braunton or could suggest a separate population.
- Kingsbridge: high numbers of bats were recorded near to sunset at the entrance of a crypt near to Kingsbridge. This should be investigated and monitored as 159 passes close to sunset suggest significant summer activity.
- Kitley: a known hibernation roost is present in this area, but high levels of activity in spring/summer suggest a summer roost could potentially also be present there or nearby, and may be providing a further link with bats to the north of the South Hams SAC towards Gunnislake and Buckland. Ringing of bats from Kitley has taken place and may shine a light on how these sites are linked in the future.
- Buckland. Very high numbers of bats close to sunset were recorded near to a loft space in Buckland and this should be investigated not just as a potential important roost, but also as a link between the South Hams SAC population and the populations in the Tamar Valley.



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Barbastelle bat results

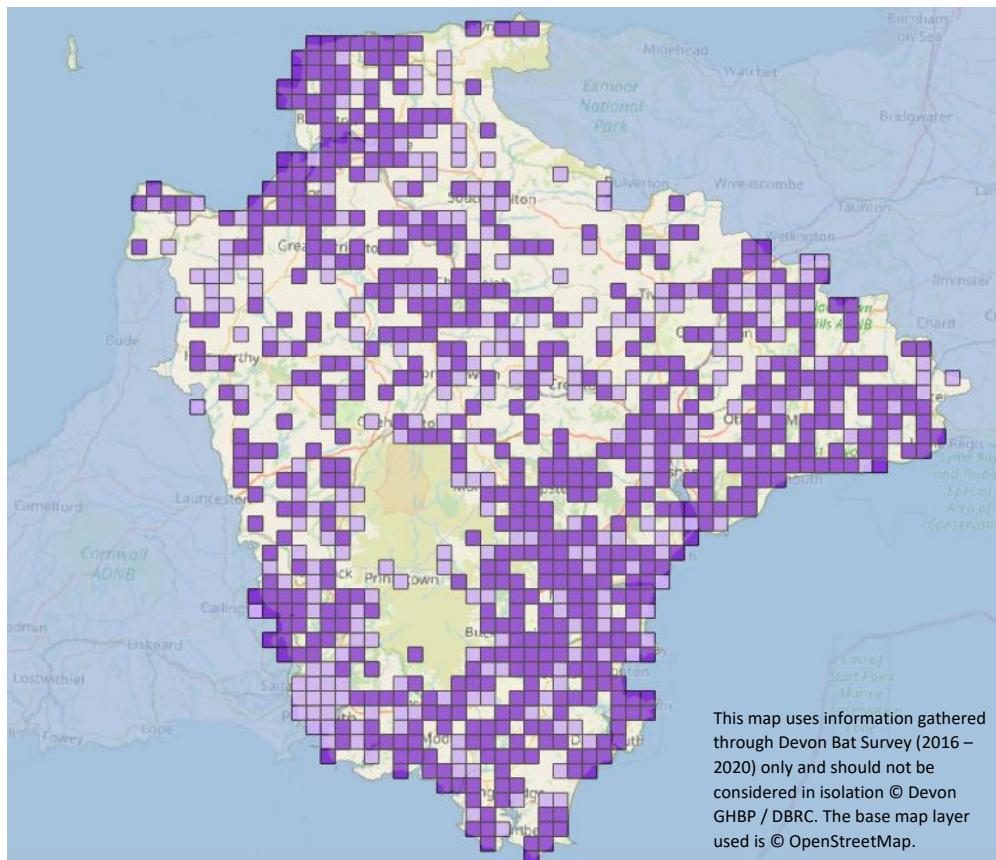


Figure 10. All tetrads surveyed in 2016 – 2020. Dark purple tetrads represent where barbastelle were detected and light purple tetrads show where they were not

Barbastelle were recorded at 59% of monad squares that were surveyed over the course of Devon Bat Survey and were found on 55% of surveys that were undertaken.

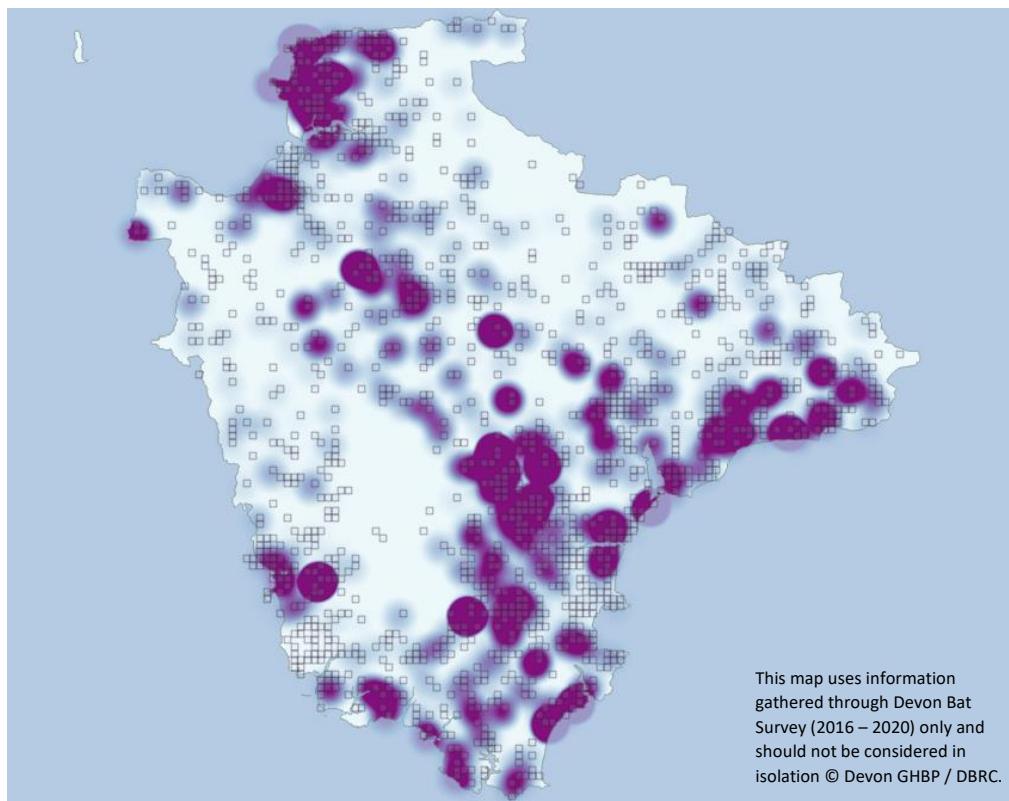


Figure 11. Heatmap of all barbastelle bat records gathered through Devon Bat Survey (2017 – 2020).

Figures 10 and 11 show the distribution of barbastelle is surprisingly widespread throughout Devon, with an apparent preference for coastal areas along the south Devon coast (with lower numbers within Torbay and Exmouth), around the Braunton area and the eastern fringe of Dartmoor.

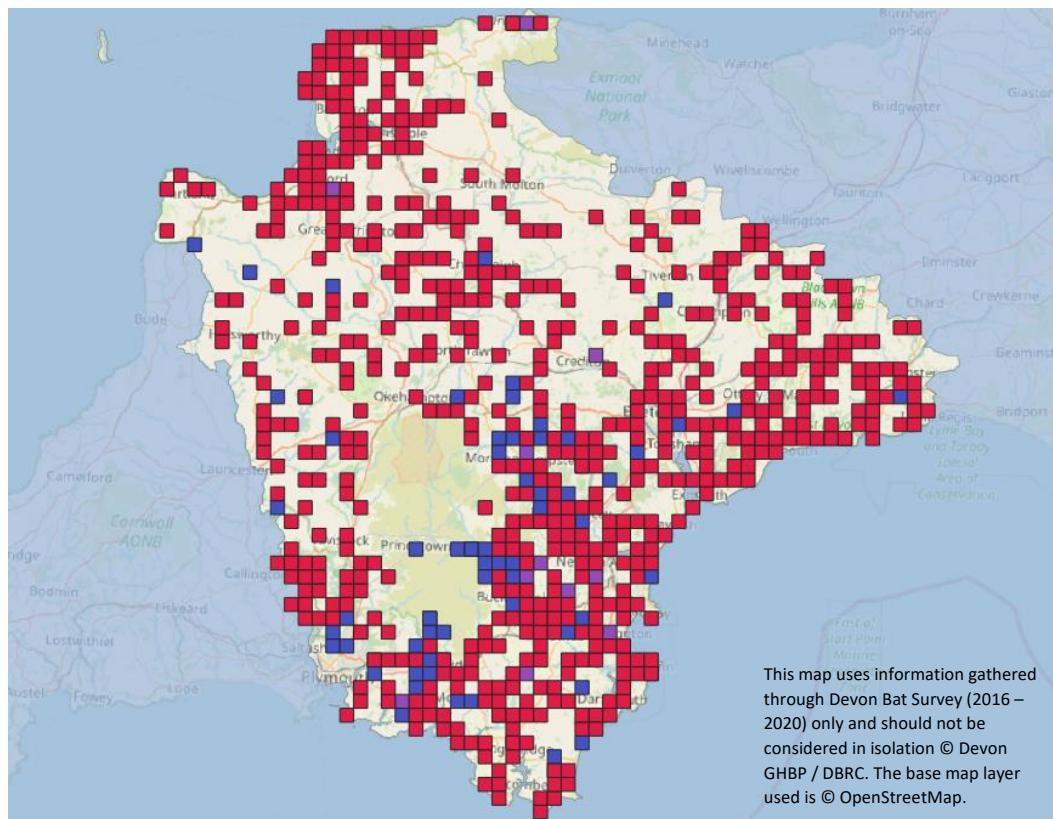


Figure 12. Tetrads where Barbastelle bat records are held by DBRC (blue), gathered through DBS (red) and held by DBRC but updated with new records through DBS (purple). Data from DBRC from 1948 – 2020, DBS data from 2016 – 2020.

Before Devon Bat Survey began, DBRC held barbastelle bat records for a total of 132 monad squares across Devon. After Devon Bat Survey, this had increased to 890. This is a remarkable (almost 800%) increase in data and strongly suggests that barbastelle were under-recorded previously across the county. Given that this is one of the UK's rarest bats and is considered 'near threatened' by the IUCN, it is especially encouraging that so much of Devon appears to support widespread populations of this species.

Table 5. Frequency at which barbastelle bats were detected each year

Year	Total Monads	Total Monads with Barbastelle	% Monads with Barbastelle
2016	129	58	45
2017	630	276	44
2018	646	335	52
2019	684	323	47
2020	214	113	53

Locations with high passes of barbastelle

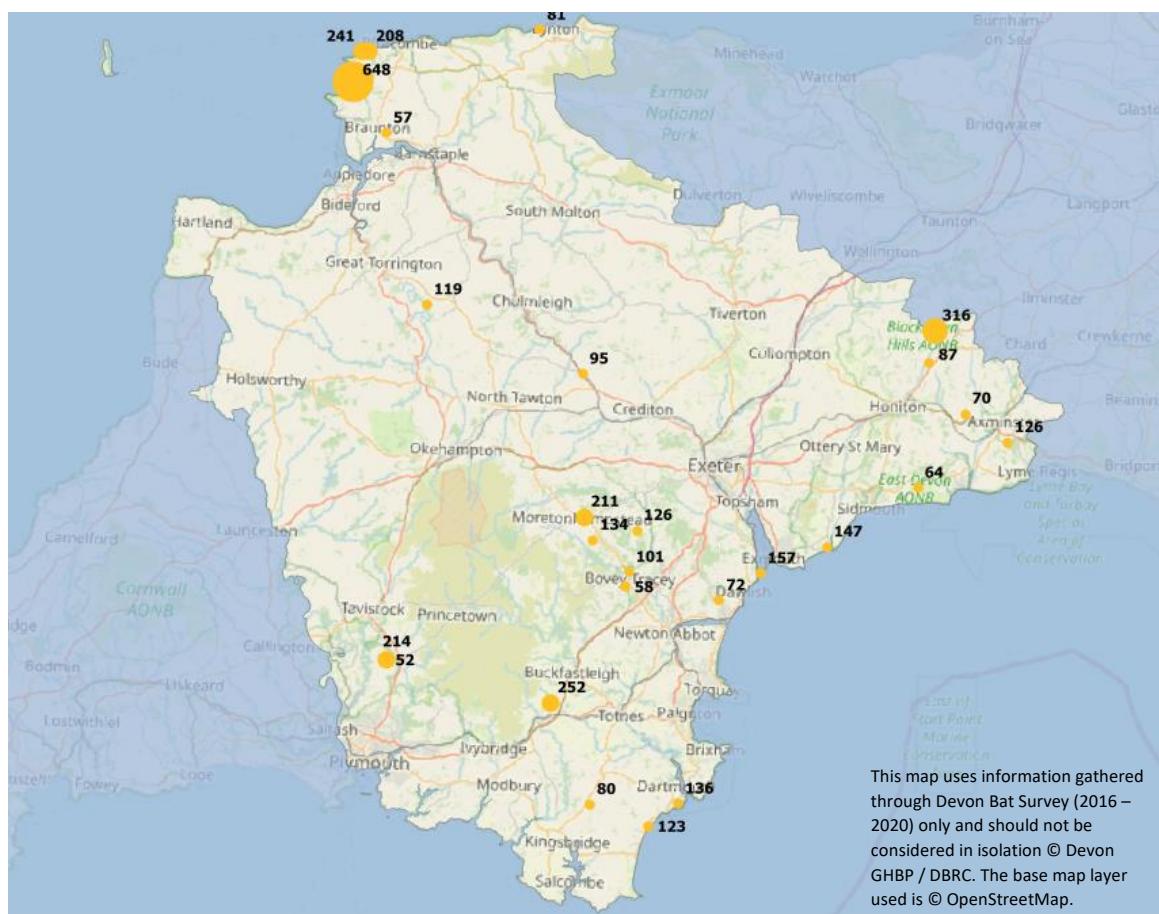


Figure 13. Total barbastelle passes at each high pass site (high passes = 50+ over the survey period of 3-5 nights).

Table 6. Sites with the highest number of barbastelle bat passes per year

Year	Total Passes	Survey period	Survey Length (in nights)	Grid Reference	Comments
2016	316	21/09/2016	1 night only	ST2010	None.
2017	241	25/09/2017	3	SS4646	None.
2018	648	19/05/2018	3	SS4542	Adjacent to [location redacted], road/track that runs adjacent to dune system, parallel to the sea. Edge of small apple orchard.
2019	24	29/05/2019	5	SS4902	On the edge of culm grassland field.
2020	214	03/08/2020	3	SX4967	Beside a small wet conservation area one side, farmland other side of hedge.

Key findings and future recommendations for barbastelle bats

- Particularly high numbers of passes of barbastelle were found on the north coast of Devon in a cluster north of Braunton, which may be due to some larger roost sites and a core area for this species. This is especially interesting as no previous data were held for barbastelle by DBRC in this part of the county. Future work in this area should look at potential roosting sites and work with land managers to raise awareness of the habitat requirements of this species.
- A cluster of passes between Bovey Tracey, Exeter and Moretonhampstead suggests that this area is also of particular importance for this species, likely in part due to the high percentage of woodland cover in the area. Working closely with land managers in this area and ‘farmer clusters’ already active will help spread the message that this area is of particular significance for barbastelle. Again only limited records of barbastelle were previously held for this area.
- As with GHBs, Buckland also appears to be a barbastelle hotspot, further suggesting future work focused in this area and that this part of Devon is particularly important for bats of all species.
- Barbastelle appears to have a close affiliation with coastal areas, particularly along the southern coast as demonstrated by the heat map and the high pass sites. Previous DBRC records did not demonstrate this and barbastelle research in the future could explore this link further.
- A few other hotspots such as near Buckfastleigh and the Blackdown Hills have also been evidenced, but in general, the sheer amount of data gathered for barbastelle suggests that this species is far more widespread in Devon than previously thought, and future DBS surveys will be useful to further understand where we would expect this species to be found.

Lesser horseshoe bat results

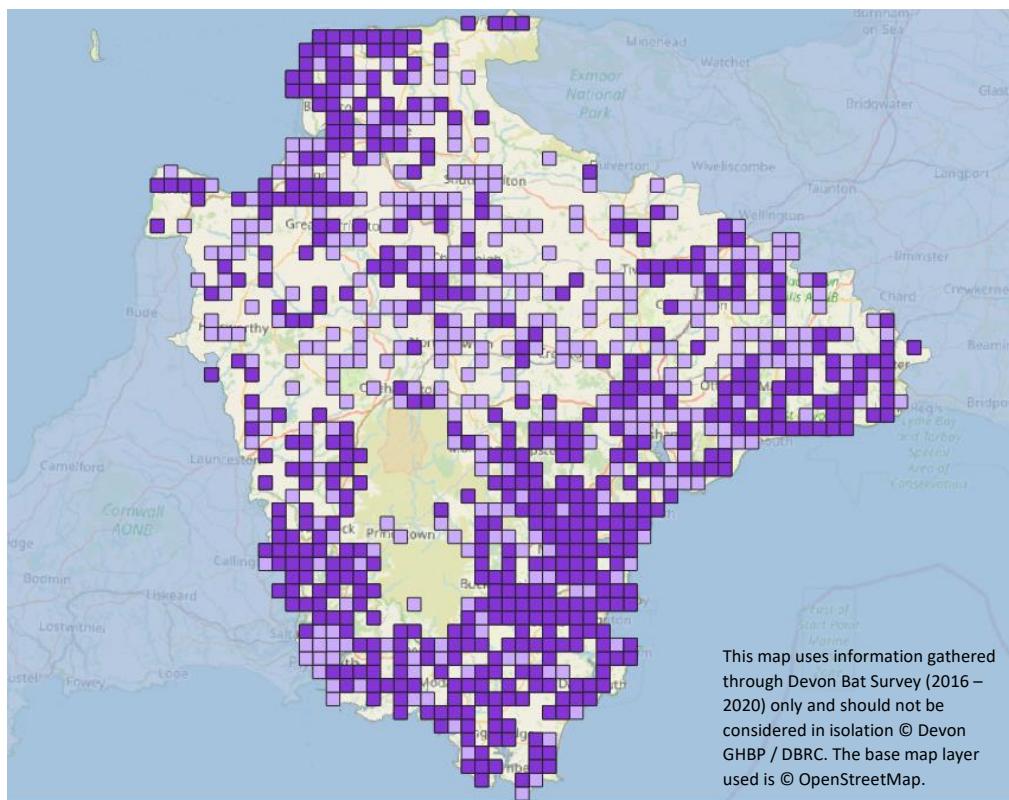


Figure 14. Total tetrads surveyed in 2016 – 2020. Tetrads where LHBs were detected are shown in dark purple, and tetrads surveyed where no LHBs were detected are shown in light purple.

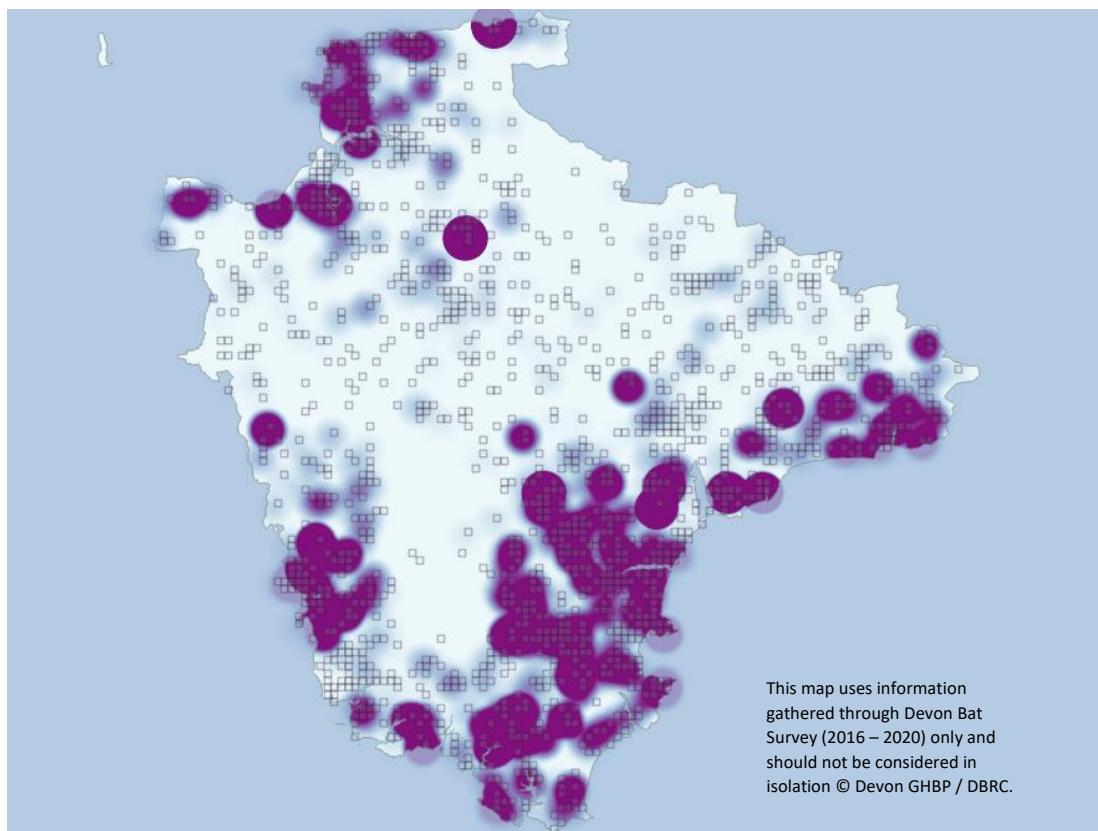


Figure 15. Heatmap of all LHB records gathered through Devon Bat Survey (2016 – 2020)

Similar to the distribution of the GHBs across Devon, LHBs show a marked preference for the south and north of the county and a general lower distribution across the central belt of the county north of Dartmoor.

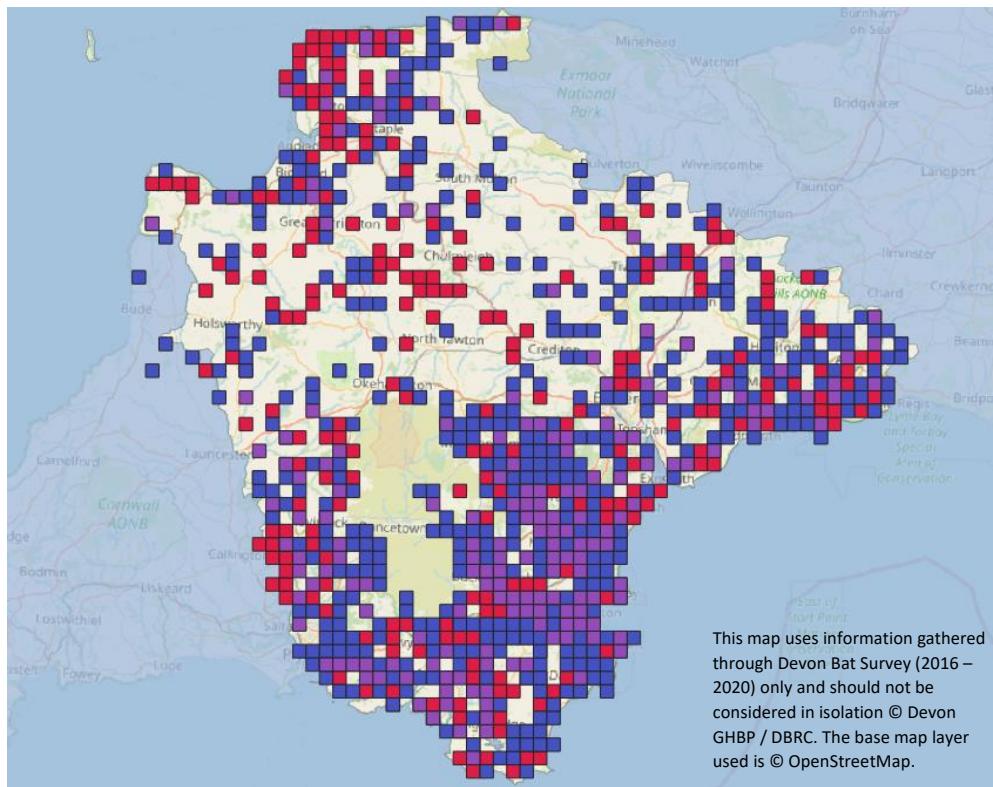


Figure 16. DBRC and DBS map Tetrads where LHB records are already held by DBRC (blue), new data gathered through DBS (red) and held by DBRC but updated with new records through DBS (purple). Data from DBRC from 1948 – 2020, DBS data from 2016 – 2020.

DBRC held LHB records for 836 monad squares prior to DBS. This has now gone up by a further 508 monad squares to 1,344 as well as updating 214 monad squares which previously held data for LHB.

LHB were recorded on 40% of surveys during DBS and 52% of monad squares. In particular, DBS has improved our knowledge of the distribution of LHBs in the northern part of Devon where relatively little data was previously held. The updated picture for the distribution of LHBs across South Devon, suggests they are very widely distributed, with old records now updated and new records filling in gaps where no data was held before.

Locations with high passes of lesser horseshoe

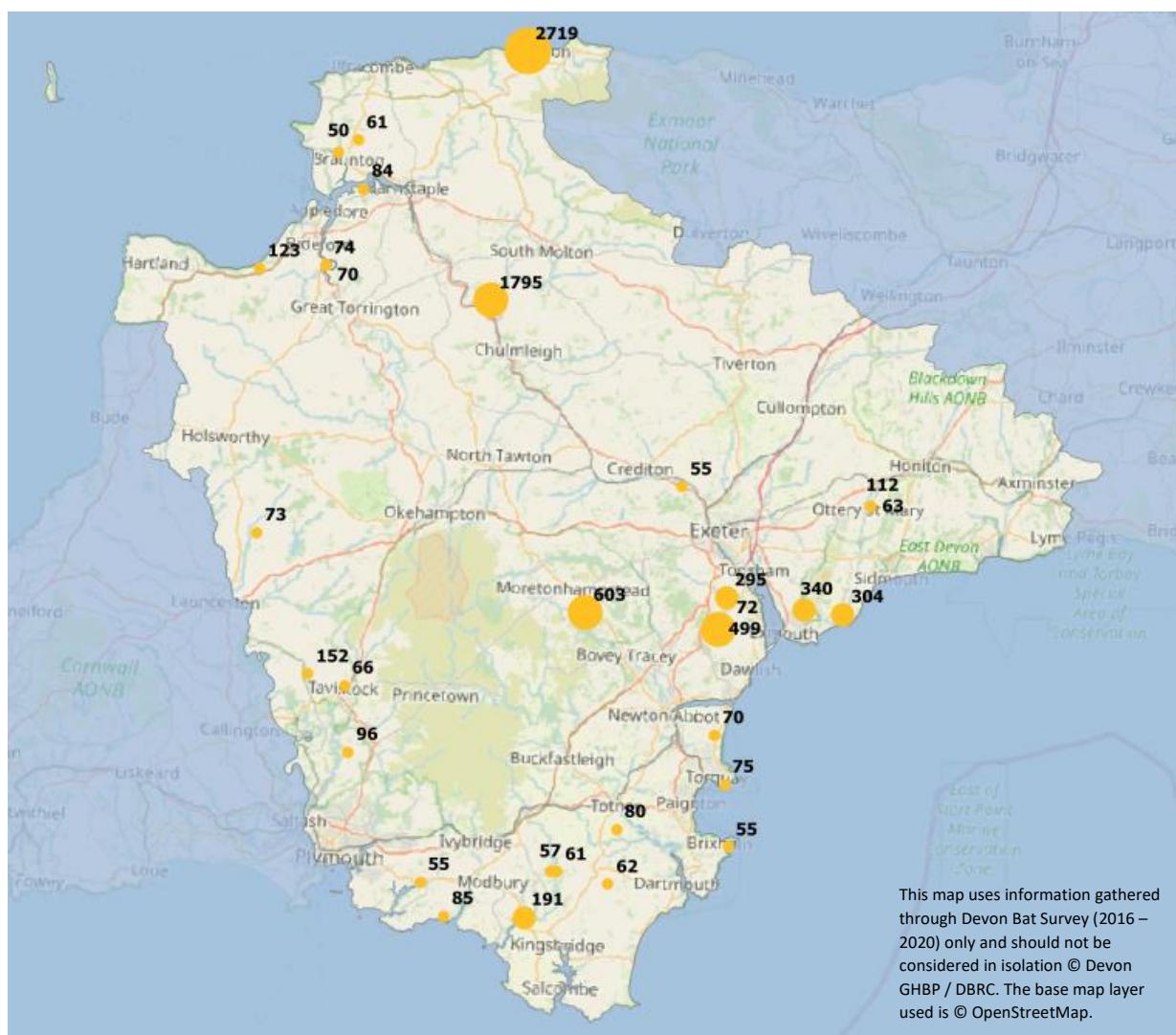


Figure 17. Total lesser horseshoe passes at each high pass site (high passes = 50+ over the survey period) for 2016 – 2020.

Table 7. Sites with the highest number of lesser horseshoe bat passes per year

Year	Total Passes	Survey start date	Survey Length (in nights)	Grid Reference	Comments
2016	499	20/08/2016	N/A	SX9281	The bats in a woodstore under a house. They can access the parts of the house underneath the main living area. This area is inaccessible to humans.
2017	84	12/05/2017	3	SS5033	In small clearing surrounded by trees and hedges.
2018	2,719	06/08/2018	3	SS6949	Detector put next to roost exit/entrance. There is a small tree immediately next to it as well as

					garden plants and bushes. Bat roost is under the [redacted] lounge.
2019	48	18/09/2019	4	SX7467	[Exact location redacted] tied to tree trunk facing slight downstream
2020	603	09/08/2020	4	SX7663	Blueberry fields

Table 8. Frequency at which lesser horseshoe bats were detected each year

Year	Total Monads that year	Total Monads with lesser horseshoe bat that year	% Monads with lesser horseshoe bat that year
2016	129	91	71
2017	630	253	40
2018	646	324	50
2019	684	283	41
2020	214	99	46

Key findings and recommendations for future LHB research

- South of the Teign Estuary: no known maternity roost records are held for this area and given the bat interest for GHBs and barbastelle also found in this area, further investigations should take place here.
- High number of bat passes (2,719) is associated with a known roost.
- Near to Ottery St Mary: no other records suggesting there is a large roost nearby are currently held by DBRC, therefore further information about this should be sought.
- High bat passes near to Exmouth ties in with historic records of summer roosting nearby, but no clear evidence of summer roosts are held by DBRC currently. This site should be visited in the summer to determine if a breeding site is present.
- High bat passes near Exminster (and associated notes indicating a roost under a house) mean this site should be investigated further. Given the large amount of bat activity for all species in this area, updating roost records for the sites around here should be undertaken.
- 191 bat passes north of Kingsbridge does not appear to be associated with any recent records of known roosts, and this part of Devon should be investigated further as an area of particularly high bat activity.

Bats in urban settings

Table 9: Percentage of monad squares within urban areas where 3 of the key Devon bat species were found (with comparison to the Devon average):

Urban Area	Total number of monad squares surveyed in urban area (2016-2020)	GHB % presence	Barbastelle bat % presence	LHB % presence
Plymouth and Plympton	38	13%	8%	23%
Torbay	34	38%	38%	50%
Exeter	25	12%	44%	36%
Average urban % occurrence		21%	30%	36%
Average % monads where species found for all DBS		37%	59%	52%

It is quite surprising that these generally photo-phobic species would be found relatively frequently in urban settings, especially so for lesser horseshoes and barbastelle bats where a third of ‘urban’ sites surveyed held these species. However, when looking more deeply at the data, it is apparent that these species are making use of linked rows of gardens between terraced houses, country parks, tree lined streets and darker areas. This highlights the importance of green infrastructure and in particular the role of gardening for wildlife in our towns and cities.

The Torbay area, appears to be especially well used by bats with the average percentage of monads holding GHBs and LHBs being roughly the same as the Devon average.

A future focus for the Devon Bat Survey could be to look more closely at urban areas to identify key flight paths through towns, engaging with people in urban areas who may not realise how much their gardens and parks are used by rare and enigmatic species, such as the bats identified in the DBS. This may not fit well with the current 1km^2 methodology designed for the county-wide survey, but is something to consider for smaller projects wishing to incorporate DBS style citizen science work in the future.

5. Discussion

The results from 2016 – 2020 indicate that common pipistrelle was the most common species found in Devon with automatic identification suggesting over 1.2 million sound files for this species, within over 94% of squares surveyed. Perhaps the most surprising result from the survey is just how widespread barbastelle bats are in Devon and in particular, hotspots in some areas have shown very high levels of activity which is especially surprising considering barbastelle have generally small roost sizes (10-20 for nursery roosts). Perhaps this is reflecting high passes by small numbers of bats at foraging grounds, but it could be showing key flight paths for high numbers of bats.

Data from the detectors placed out across urban areas show us how these sites shouldn't be ignored for bat conservation and provide real opportunities for engaging with people in these areas in the future.

The 3 bat species focused on in this report all show hotspots of activity in the following areas:

- South Hams
- North of Braunton
- Fringes of Dartmoor
- Branscombe area
- Buckland and Gunnislake areas

These hotspots are interesting in that they are hotspots for all 3 of the key species looked at for this report, indicating that what is good land management for one bat species is likely to be beneficial to others as well.

Ongoing work to analyse the DBS results will look at the noctule, serotine, Leisler's, Natusius' pipistrelle, long-eared and myotis species recorded and their distribution.

Future direction of DBS

The 2016 – 2020 DBS was based on a largely random data collection method with no direct control over where detectors were being placed, beyond a 1km² area and guidance on places where bats are likely to be found. This allowed for participants to place detectors in areas they themselves were most interested in understanding better, and indeed the increasing popularity and repeat use of the detectors by volunteers year on year show that this methodology is likely to continue to gather vast data sets into the future if funding is secured.

Different approaches to undertaking DBS

The future of DBS could be scaled up to include surrounding counties as well as Devon. This would help us to better understand how meta-populations of bat species may be connected beyond county boundaries. For example a cluster of activity on the north coast of Devon may be due to a population over the border in Somerset and outside of the scope of the DBS.

Where areas of interest are identified, such as those highlighted in this report, then more in depth use of detectors (at a rate greater than 1 per km²) could be encouraged, such as in urban areas. This may be of particular interest to take forward while there is a break in funding for DBS.

Honing the approach

Year on year, the methodology, data collection and storage improved for the DBS, greatly improving the speed and efficiency of the process. By the final 2 years, data was inputted into an access database rather than excel spreadsheets allowing for a far easier way of interrogating information regarding species and habitats compared with previous years. In the future we would recommend:

- Ensuring all data including habitat data continues to be inputted into current database design
- Results at the end of each survey year are shared with advisers on the ground and added to existing data sets wherever possible
- A summary report for the whole year (for Devon or by region) is circulated to existing volunteers and the public, so that they can compare their results to the bigger picture and encourage both old and new survey volunteers to take part the following year.

Advances in acoustic ecology

The DBS methodology has been shown to be a highly effective method of gathering data and focusing conservation effort. Recent improvements in auto ID software means that this same approach can be adapted in the future for identifying other species such as crickets, small mammals (including dormouse and harvest mouse) and bird species. This raises the potential for this methodology to be useful for understanding a great deal of our local wildlife, enabling people to value and better understand their local wildlife along the way.

6. summary

The DBS has demonstrated how successful a citizen science project can be in engaging with and inspiring the public, increasing understanding of our natural world, raising new research questions and further improving our ability to conserve wildlife.

The first 5 years of DBS has had an impressive reach and impact in terms of engagement and information gathering. There can be no doubt that the initial aims of DBS as set out at the start of this report have been met, and expectations often exceeded. There is a great deal of momentum which has been built up during the project, as evidenced in the repeat engagement and growing volunteer participation numbers year on year. It is not hyperbole to say that all those involved hope that this momentum and goodwill to the DBS can be picked up neatly in the future and continued where it left off.

In terms of bat data gathered, we now have a far better understanding of the distribution and key areas for bat species across Devon due to DBS. Future bat-friendly management advice and roost monitoring can be more efficiently targeted at areas identified as key locations through this report and the information gathered over the course of 2016 – 2020.

7. Acknowledgements

Firstly, thank you to all the fantastic monitoring centres who acted as pick up and drop off points for the detectors and associated recording sheets, SD cards and envelopes. This sometimes required considerable amounts of time and effort by staff and volunteers, and it was all very much appreciated. Without your help, the DBS could never have worked.

Thank you to each and every volunteer who took the time to pick up detectors, put them out, and send us SD cards. A brilliant effort, and we hope that seeing the incredible amount of data generated through your work fills you with a sense of pride.

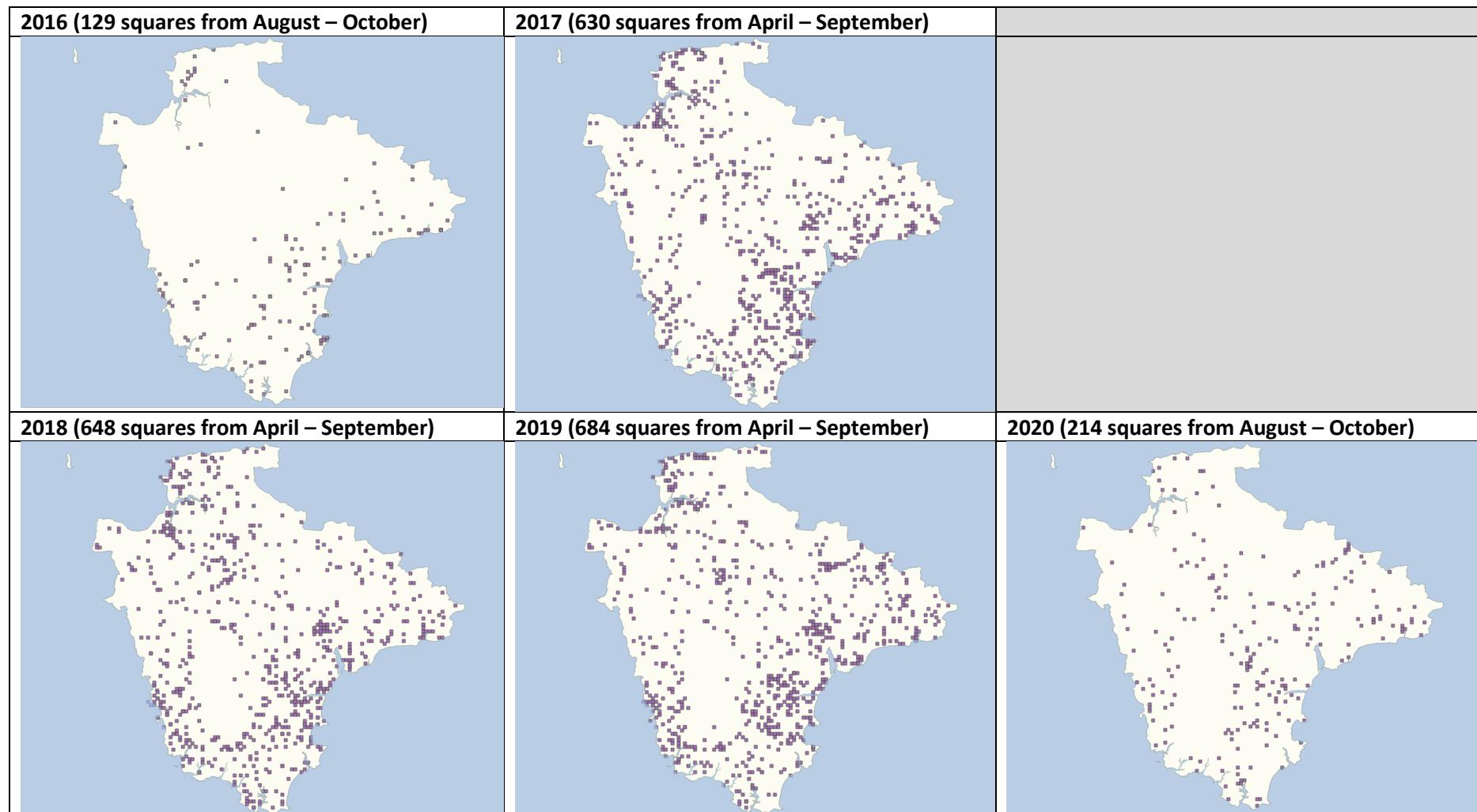
A huge thank you to Stuart Newson and his team at the British Trust for Ornithology for helping us at every step of the way. Without their expertise, especially the developed software and report creation scripts in 2018 – 2020, booking system and pioneering work with Norfolk Bat Survey, Devon Bat Survey could never have achieved what it has.

Another big thank you to Steve Markham who provided immensely useful expertise in R-coding to help us create the reports sent out to participants in 2016 and 2017. This saved vast amounts of staff time and made the survey feedback much more professional and less prone to mistakes.

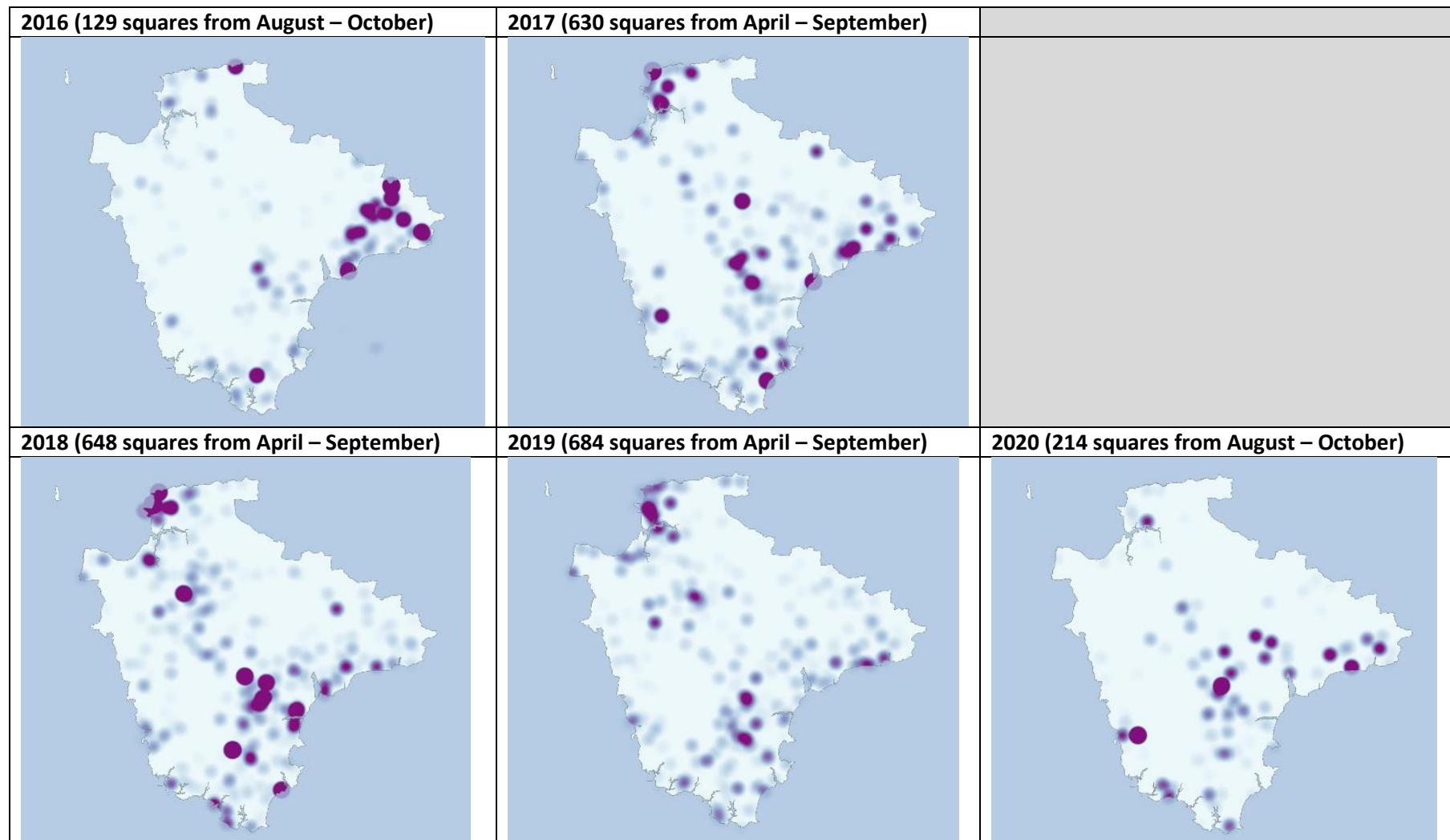
Thank you to all volunteers who helped us with verifying the Devon Bat Survey data in the office and at home: Bill Potter, Jess Munday, Kate Smethurst, Caleb Compton, Lizzy Winters, Nick Pratt and Jamie Butt.

Finally well done and thank you to all on the delivery team and especially to Elinor Parry who has worked on the DBS as the ‘Survey Assistant’ for the final 2 years of the project on all the technical, coding and day to day administration of the project and compiled the maps, tables and associated information for this final report. Without Elinor’s work, the DBS would not have been run so smoothly and been so well interpreted.

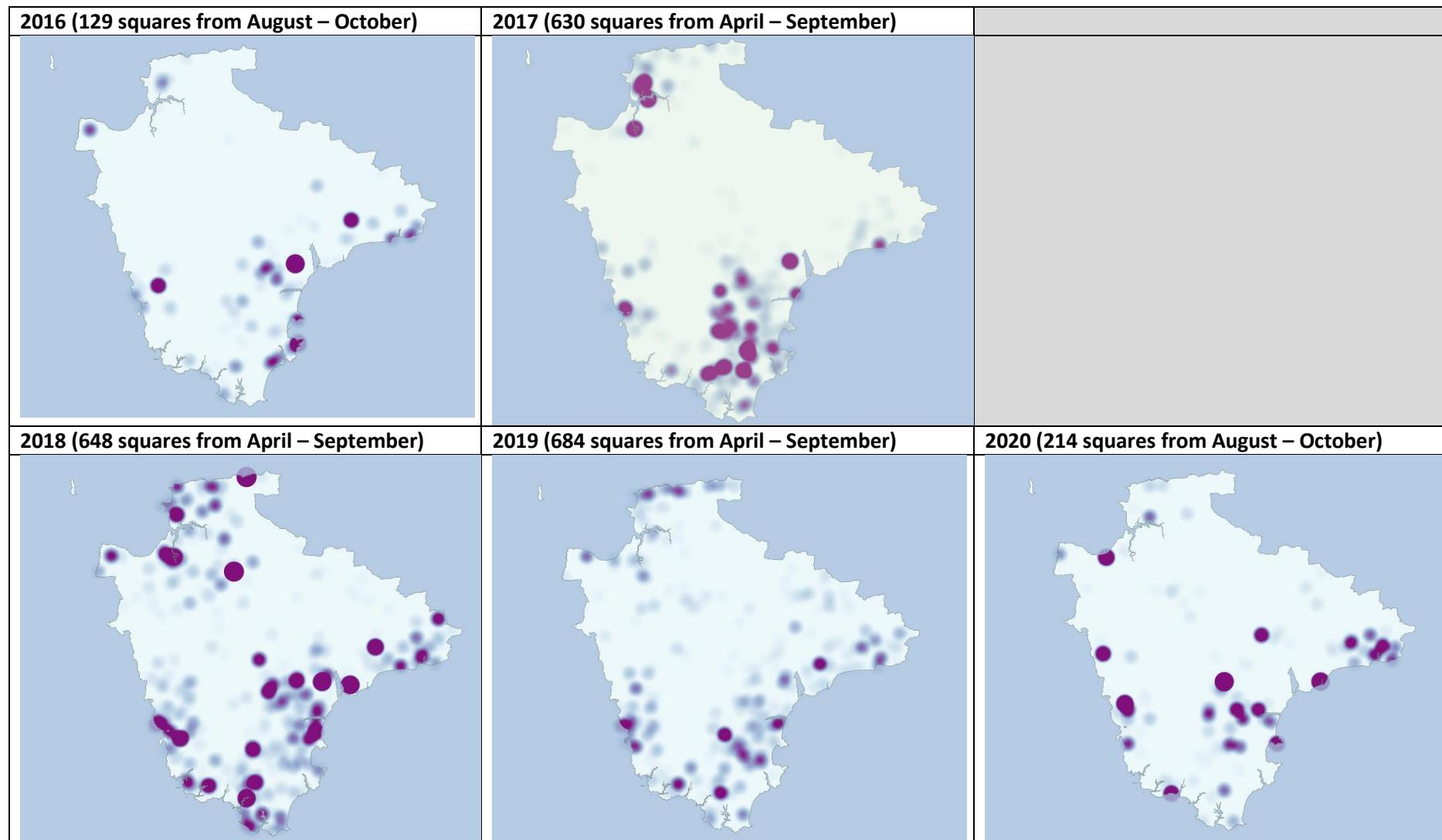
Appendix 1 – Location of survey squares each year



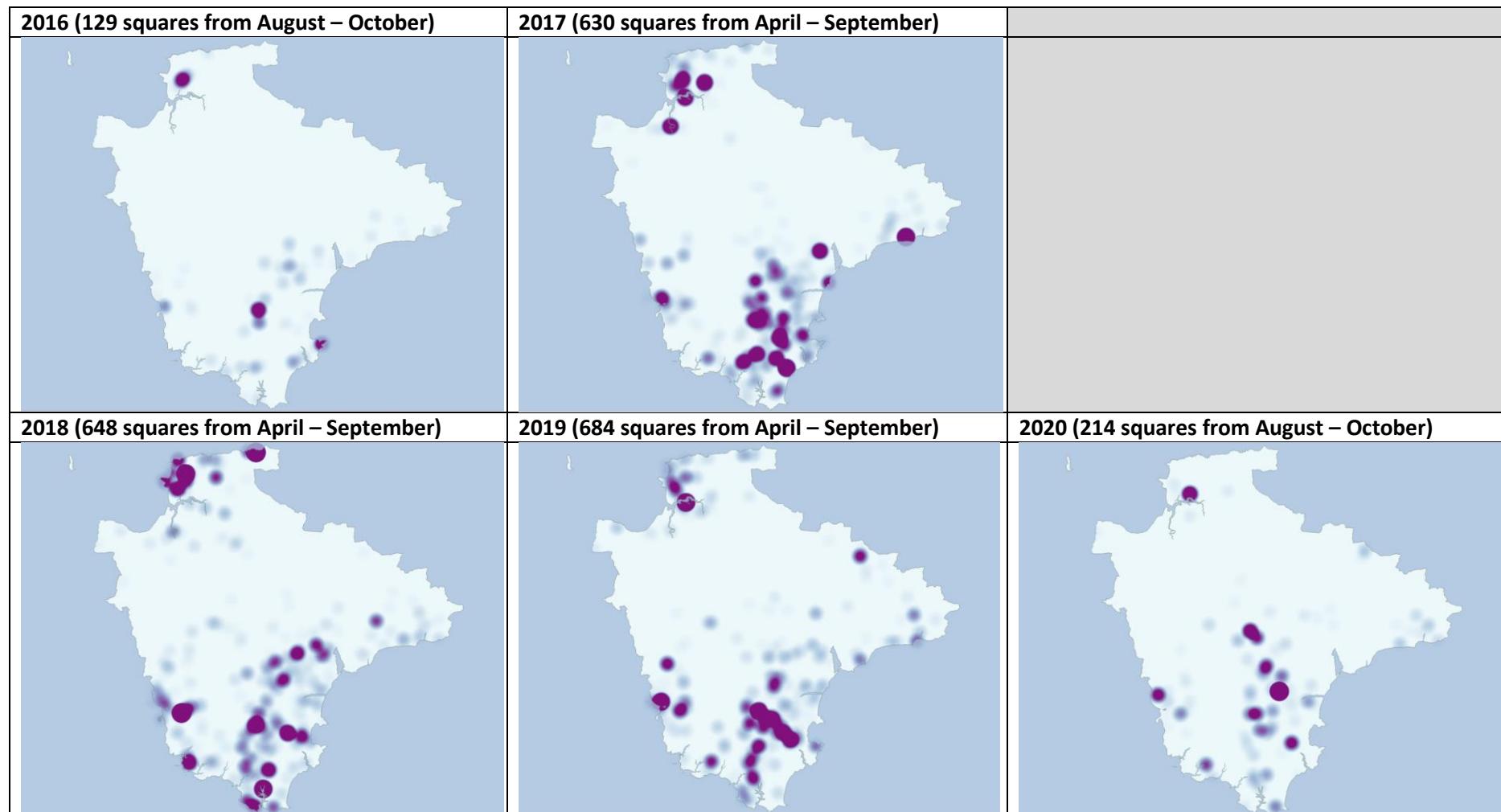
Appendix 2 - Barbastelle bat heatmaps over time



Appendix 3 – Lesser horseshoe heatmaps over time



Appendix 4 – Greater horseshoe heatmaps over time



Appendix 5. Survey and species coverage summary tables

Table I. Total monad squares surveyed through Devon Bat Survey each year, and total monad squares where each species was found per year (this includes monads which were surveyed multiple times in a given year)

	2016	2017	2018	2019	2020	Grand Total
DBS	154	706	722	747	224	2553
BABA	58	276	335	323	113	1105
GHB	63	230	270	216	52	831
LHB	91	253	324	283	99	1050

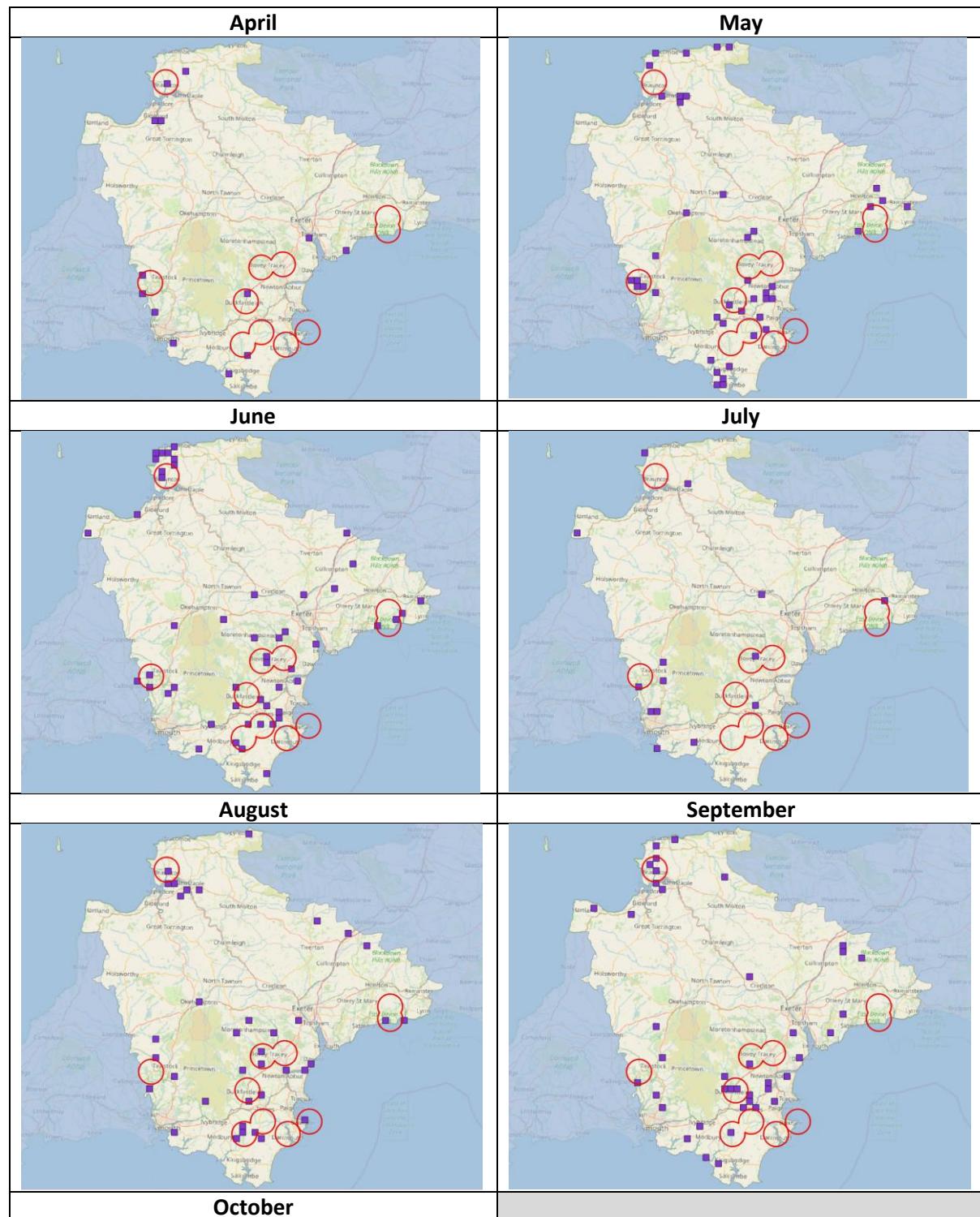
Table II. Percentage of all monad squares surveyed where each species was found each year

	2016	2017	2018	2019	2020
BABA	38	39	46	43	50
GHB	41	33	37	29	23
LHB	59	36	45	38	44

Appendix 6. Monthly GHB Activity from DBS 2019

Future effort to understand where bat populations are found over time (in relation to known roosts) would be useful - here is an example of 2019 monthly passes, but useful insight would only be gathered through larger datasets.

The data below groups all activity by month – so some surveys will have been split up. The core sustenance zones of 11 priority greater horseshoe bat maternity roosts are shown in red.



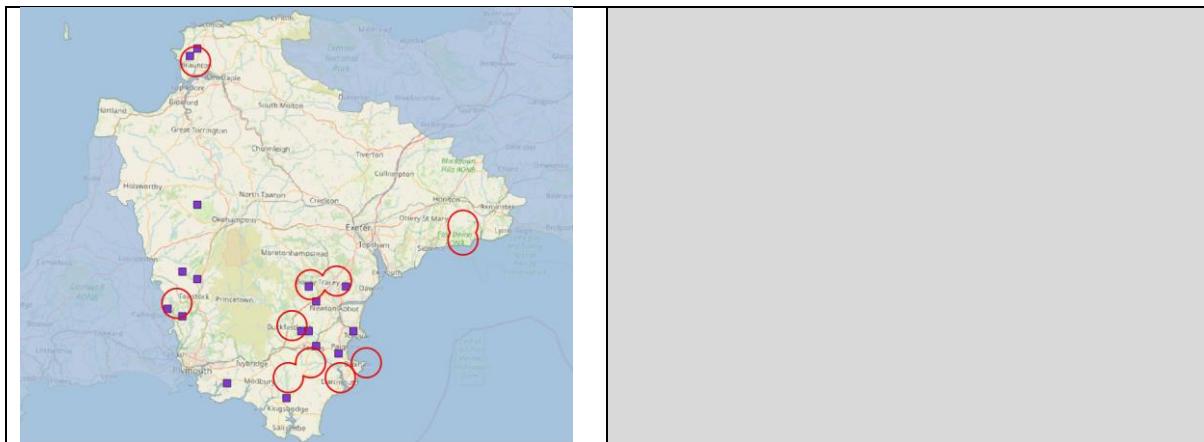


Table 7. breakdown of 2019 survey effort by month (NB. Data was split into months based on start date of each survey).

Month	Surveys carried out	Total surveys where Greater horseshoe bats found	% surveys with GHBS
April	86	14	16
May	120	44	37
June	132	53	40
July	117	15	13
August	123	39	32
September	101	42	42
October	70	17	24

Appendix 6. Example of the Devon Bat Survey Report sent to survey volunteers

Page 1



Devon Bat Survey 2019

Introduction

Thank you for taking part in the Devon Bat Survey. The records that you have helped to provide will help us to work out how bats are using our landscape. This survey is being run as part of the Devon Greater Horseshoe Bat Project, which is a 5 year partnership project of 18 organisations led by Devon Wildlife Trust and is supported by the National Lottery through the Heritage Lottery Fund, as well as other funders.

There are 18 species of bat in Britain and they all have different needs, so some are more likely to be found in dark, rural areas such as the greater horseshoe bat, and others are happy in towns and cities, like the common pipistrelle. All the bats in the UK eat insects, so they are great natural pest controllers! This means that their droppings are made up of tiny bits of insect, so they are crumbly and dry.

Bats find their prey through echolocation - this is where the bat calls at a very high frequency (most humans cannot hear this - although children are sometimes able to) and listens for the return call as it bounces off an object. Horseshoe bats have a special nose-leaf that is shaped like a horseshoe which helps them to direct their calls. This helps them to build up a map of their surroundings and find their prey. It is these calls that the bat detector you borrowed has recorded, and many of these are distinctive to a particular bat, or a group of bats, allowing us to work out what species have been detected.

This report will tell you what bats have flown past your detector. It is a brief report using automatic identification software and some of the results may change once we manually look at the calls in more detail. It does not give an exact number of bats, but tells you how many times a bat of each species has been recorded passing by - it could be one bat flying past lots of times! It will also give you some information on each species of bat.

The records that you have helped to provide will allow us to better understand how bats are using our landscape and how they are distributed across Devon. The records will help us to direct future conservation strategies. This report should not be reproduced without prior approval and should not be used for any development planning purposes.

We hope that you have enjoyed taking part in the survey and will take part again next year.

Many thanks



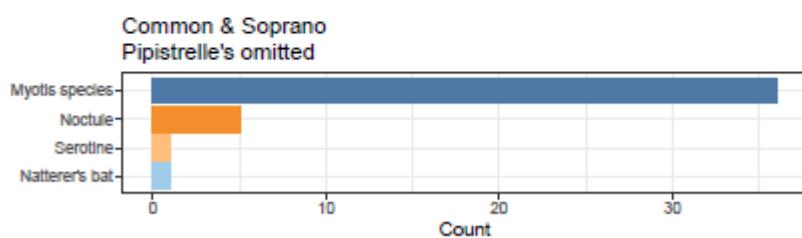
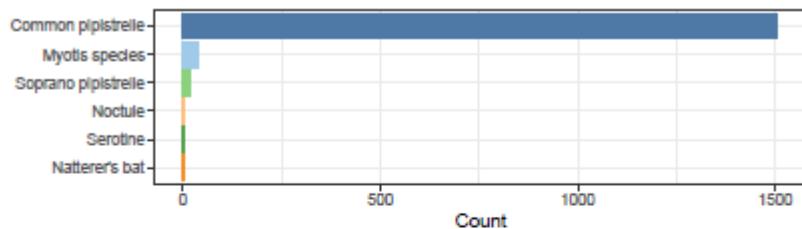
Bat survey results

Survey results for SS [REDACTED]

Bat species detected:

Our provisional analysis of the recordings detected the following species. The numbers relate to the number of bat passes rather than the number of individual bats.

Species	n
Common pipistrelle	1506
Myotis species	36
Natterer's bat	1
Noctule	5
Serotine	1
Soprano pipistrelle	20



Common pipistrelle, *Pipistrellus pipistrellus*

Common pipistrelles are the most common and widespread of all British bat species. They are found in lots of places, including towns and cities, as well as in the countryside. They are small, and their flight is fast and jerky as they pursue small insects which they catch and eat whilst flying. A single pipistrelle can consume up to 3,000 insects in one night!

Noctule, *Nyctalus noctula*

The noctule is one of the largest British species and is striking with its sleek golden brown fur and very dark face and wings. It flies high and fast in a straight line with occasional steep swoops as it pursues insects and catches them on the wing. As a fast-flyer it is less vulnerable to predators so emerges from its roost early, sometimes even before sunset, and is often seen flying over tree-tops. Noctules favour open habitats such as pasture, woodland edge, marshland and parkland, and they are also commonly found close to rivers and lakes.

Soprano pipistrelle, *Pipistrellus pygmaeus*

The soprano pipistrelle was discovered as a different species to the common pipistrelle in the 1990s - they are very similar but they use slightly different echolocation calls and there are subtle differences in how they look. They also tend to roost and hunt in slightly different places, with the soprano pipistrelle favouring river habitat and wetland areas.

Serotine, *Eptesicus serotinus*

The serotine is one of Britain's largest bat species and usually one of the first to appear in the evening. It has a leisurely flight style, with distinctive short glides, steep descents and circling over open areas. Serotines look for food over a range of open habitats such as pasture, parkland, woodland edge, tall hedgerow, over water bodies and will also hunt over streetlights in suburban areas.

Natterer's bat, *Myotis nattereri*

This medium-sized species has long, slightly curved ears, and a fringe of very stiff bristles along the trailing edge of its broad tail membrane. Natterer's bat is highly agile in tight spaces, making quick, sharp turns. This means it can hunt very close to vegetation, picking up insects off leaves and twigs and catching insects flying close to dense vegetation. They tend to hunt in dense woodland, along tree-lined rivers and over water bodies, but are also found in woodland clearings, meadows and parkland.

Myotis species, *Myotis spp.*

The Myotis are a group of bats which includes Alcathoe, Bechstein's, Brandt's, Daubenton's, Natterer's and Whiskered bats. They all make very similar sounds which mean that sometimes it is very hard to tell them apart from their recordings alone.

Appendix 7. List of host centres for Devon Bat Survey

Name	Year(s) hosted a detector
Avon Mill Garden Centre	2016-2020
Beehive Centre	2016-2019
Beer Village Stores	2016-2017
Berry Head Visitor Centre	2016-2017
Braunton Countryside Centre	2016-2020
Buckfastleigh Pool	2016
Chudleigh Town hall	2016-2020
Stover Country Park	2016-2020
Tamar Valley Centre	2016-2020
The Flavel	2016-2017
The Globe Inn	2017
The Watermark	2017-2019
Otterton Mill	2017
Combe Martin Museum & tourist information point	2017-2019
Devon Wildlife Trust Cricklepit Mill	2017-2019
The Dartington Hall Estate	2017-2019
Devon Wildlife Trust Cookworthy Forest Centre	2017-2019
Eggesford Garden Centre	2017-2018
Bickleigh Mill	2017
Mole Avon Forecourt	2017-2020
Puffing Billy Trading Co.	2017-2019
Occombe Farm	2018-2019
Lydford Gorge	2018
Poole Farm	2018-2019
Blackdown Hills AONB	2018-2019
Quince Honey Farm	2018-2020
Seaton Jurassic	2018-2020
Homeleigh Crediton	2019-2020
Grand Western Canal	2019-2020