Cinderford Northern Quarter

Automated and Flight-line Bat Survey 2016

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Contents

1 Summary

1.1 BSG Ecology was commissioned by Forest of Dean District Council (FoDDC) to provide pre-construction baseline survey information on bats to inform future monitoring of the Cinderford Northern Quarter (CNQ) regeneration programme. These surveys form part of the implementation of an overall bat monitoring strategy.

1.2 Two distinct survey methods were used to describe and quantify bat activity (focussing on lesser horseshoe bats *Rhinolophus hipposideros*): automated bat detector surveys of two woodland areas; and, flight-line corridor surveys at three Survey Corridors (SCs) in proximity to proposed road-crossing points. The aims of the study were to provide data appropriate to form a baseline for future monitoring, and to provide repeatable monitoring methods for both survey types.

1.3 The flight-line corridor survey areas were selected as they are close to known commuting routes for lesser horseshoe bats and locations where crossing points for bats will be installed under proposals for the CNQ spine road. They are also locations where commuting bat activity is likely to be concentrated and can be observed and quantified effectively. During each survey two surveyors, two automated bat detectors and a single thermal imaging camera was used at each SC to increase detections of bats. The locations for some of these were adjusted to optimise the effectiveness of each survey.

1.4 Automated bat detector surveys were undertaken in two woodland areas (eastern and western) identified by FoDDC as potential woodland mitigation areas. Three locations were chosen within each area of woodland to match the following criteria: they are at least 30 m apart from each other; and, they are at habitat interfaces where high levels of bat activity would be expected.

1.5 Six flight-line surveys were carried out between May and August with a minimum of 321 and maximum of 363 lesser horseshoe bats recorded, averaging 53.5 ± 22.6 bats per survey. The highest minimum count was 90 bats in August with a low of 28 bats during the first June survey. At each SC the total count range was 64-69 (SC1), 122-153 (SC2) and 135-141 (SC3) bats. Overall the minimum and maximum counts for each survey (and each SC) did not show great variation. It was possible, in most cases, to ascertain how many bats crossed each SC by combining the datasets. It is considered, as a result, that the counts recorded (using three methods) are robust and can be relied upon.

1.6 Four periods (each five nights) of automated bat detector survey were carried out during June-August at six locations. A total of 15,999 passes from at least eleven species of bat were recorded. These species included lesser horseshoe bat, greater horseshoe bat *Rhinolophus ferruquinum*, common pipistrelle *Pipistrellus pipistrellus*, soprano pipistrelle *Pipistrellus pygmaeus*, Nathusius' pipistrelle *Pipistrellus nathusii*, noctule *Nyctalus noctula*, Leisler's bat *Nyctalus leislerii*, serotine *Eptesicus serotinus*, barbastelle *Barbastellus barbastella*, long-eared bat *Plecotus* sp., and *Myotis* sp. Recording eleven species of bats is not considered to be unusual bearing in mind the type and quality of habitats locally and in the wider area. The relatively high recorded activity rate indicates the quality of the habitat in the area for a wide range of bat species and gives confidence that the survey has robustly captured bat activity in the areas.

1.7 Lesser horseshoe bats were recorded at all of the automated detector locations and from all 24 automated detector deployments. Higher levels of activity were recorded in the western woodland survey area compared to the eastern (1.6 B/h and 0.3 B/h respectively). The highest rate of activity was recorded at A1C (2.9 B/h) which is located close to the commuting route that crosses SC2. The nocturnal activity patterns showed that passes were typically being recorded first by detectors within 20 minutes of sunset, with a peak in activity during 20-40 minutes after sunset.

2 Introduction

2.1 This report has been prepared by BSG Ecology. BSG Ecology was commissioned by Forest of Dean District Council (FoDDC) to provide pre-construction baseline survey information on bats to inform future monitoring of the Cinderford Northern Quarter (CNQ) regeneration programme. These surveys form part of the implementation of an overall bat monitoring strategy (Berthinussen & Altringham, 2015), that was required under Condition 23 of permission P0663/14/OUT.

Scope and aims of study

2.2 The scope of the study was to use two distinct survey methods to describe and quantify bat activity (focussing on lesser horseshoe bats *Rhinolophus hipposideros*) at distinct study sites within the CNQ area. The survey methods are described in detail in Section 3 and are summarised below:

- Automated bat detector surveys of two woodland areas.
- Flight-line corridor surveys at three Survey Corridors (SCs) in proximity to proposed road-crossing points.

2.3 The aims of the study were as follows:

- To provide data appropriate to form a baseline for future monitoring.
- To provide repeatable monitoring methods for both survey types.
- To trial the use of Thermal Imaging (TI) cameras to supplement standard methods.

3 Methods

3.1 The survey methods were based on an initial specification provided by FoDDC with further detail provided in Berthinussen & Altringham (2015).

Flight-line corridor surveys

Selection of survey locations

3.2 Surveys were undertaken within three flight-line survey areas initially identified by FoDDC. These areas were visited by Alastair Chapman of FoDDC and Matthew Hobbs of BSG Ecology on 16 May 2016. During/following this visit and prior to surveys commencing, the location of each SC was refined and locations for surveyors, bat detectors and TI cameras were determined.

3.3 The initial survey areas were all selected according to the following criteria:

- They are close to known commuting routes for lesser horseshoe bats as determined from previous surveys carried out in the CNQ area (see lesser horseshoe bat flight-line plan in Appendix 1).
- They are close to locations where crossing points for bats will be installed under proposals for the CNQ spine road.
- They are locations where commuting bat activity is likely to be concentrated (at 'pinch points' where vegetative cover is less dense as opposed to homogeneous woodland cover), and can be observed and quantified effectively.

3.4 The extents of the SCs, as well as the location of surveyors, bat detectors and TI cameras are shown in Figure 1 (in Section 7) and the rationale for their selection is explained below. Three surveyors were used for each of the SCs during the first survey and this was reduced to two thereafter. Photographs of each SC are provided in Section 8 (Photographs 1-3).

Survey Corridor 1

3.5 SC1 is an open, linear clearing ca. 40 m in length that runs roughly north-south through deciduous woodland. It is located just to the south of the A4136 road, adjacent to and west of the proposed CNQ spine road, and intersects with what was identified in previous studies as a minor lesser horseshoe bat flyway (Flyway 4, see Appendix 1). It is ca. 200 m west of the main purpose built bat roost (see Figure 1).

3.6 Surveyors were positioned facing each other at the northern (Surveyor 1) and southern (Surveyor 2) ends of the clearing. Surveyor 2 also used a TI camera (always the A35 camera – see below) which faced north (see below for further details). Two automated bat detectors (see 3.25 and Appendix 2 for details of bat detector used) were also located within the SC. The layout of SC 1 was kept the same throughout the surveys.

Survey Corridor 2

3.7 The location of SC 2 was changed half-way through the surveys following the discovery of a previously unnoticed commuting route across the small road, which turns east away from the north-south running road/track. The general area of SC 2 was chosen as it has been identified as intersecting a major lesser horseshoe bat flyway. Flyway 1 (Appendix 1) heads south from the roost (which is ca. 170 m north-north-east) through woodland and bats apparently cross the road at up to three different points (flyways 1A, 1B, and 1C). The route of the proposed spine road is just to the south of the SC, as is a proposed location for a bat mitigation culvert. During the first three surveys, attention was focussed on these three crossing points with few bats recorded (Figure 1, SC 2a). During the fourth survey, a stronger commuting route was noticed a little further to the east and the focus switched to this flyway (close to 1C) for the remaining surveys (Figure 1, SC 2b). For the final two surveys the T650 camera was used as opposed to the A35 camera.

Survey Corridor 3

3.8 SC 3 is an open, linear clearing ca. 35 m in length that runs roughly east-west through deciduous woodland with a rectangular block of coniferous woodland adjacent to the north-east corner of the SC. The clearing bisects a ca. 50 m wide linear strip of woodland which forms a major lesser horseshoe bat flyway (Flyway 2) between a lake to the east and a brickworks to the west. It is ca. 200 m west of the main purpose built bat roost.

3.9 At the western and eastern ends of SC 3 are thick bands of scrub and trees and surveyors were positioned facing each other at the western (Surveyor 1) and eastern (Surveyor 2) ends of the clearing. Two automated bat detectors were also located within the SC. The layout of SC 1 was kept the same throughout the surveys, except for a change in position of the TI camera, from the western end for the first two surveys to the eastern end for the final four surveys. The A35 camera was used at this location for all surveys, except for the third and fourth surveys.

General methods

3.10 The survey consisted of counting numbers of commuting bats visually with visual surveyor data supplemented by the use of automated bat detectors as well as TI cameras. At each SC, two surveyors (with heterodyne detectors tuned to the typical echolocation call frequency of lesser horsehoe bat – ca. 110 kHz), two automated bat detectors and a single TI camera was used to produce a total count of commuting lesser horseshoe bats. Other species of bats were not noted by surveyors unless clear and regular commuting behaviour was observed. For example foraging pipistrelle bats were not recorded to prevent undue distraction to surveyors.

3.11 Six surveys were carried out approximately every two weeks during the late spring/early summer with one in late May, two in June and July, and one in early August (the main breeding season). Surveys were carried out in optimal weather conditions, where possible (temperature > 7 °C, wind < 20 km/h, no rain).

3.12 Surveyors used standardised proforma to record the time of each observation, the direction and location of flight, whether a bat was seen and heard (or one or the other), and any other relevant notes. These data were summarised to give a direction of ‘out’ or ‘back’, i.e. from or to the direction of the roost or a note that the bat was heard but not seen (and direction could not be given).

Materials and data analysis

Thermal imaging cameras

3.13 During each survey three TI cameras were used. For the first two surveys, one model of camera was used, the FLIR A35. For the final four surveys, two FLIR A35 cameras and a FLIR T650sc were used, with the T650sc used at SC 3 for surveys three and four and at SC 2 for surveys five and six. The basic set up for each camera is described below.

3.14 Post-processing of video files was carried out for each camera following the surveys. Videos were analysed using FLIR ResearchIR MAX (Version 4.30.1, FLIR, 2016) software. It was not possible to take direct time measurements from recordings and the time of each bat pass was calculated by dividing the length of the recording (each recording was 10 minutes) by the total number of pixels in the video. This way the pixel number could be converted to a time using a simple formula.

3.15 Bats were not identified to species level from video recordings.

FLIR A35

3.16 The A35 camera does not have a built-in battery or an LCD display. Cameras were connected to a tablet computer via an Ethernet cable and connected to an external 12V battery. Live video was displayed using FLIR ResearchIR MAX and recorded in 10 minute long segments for the duration of each survey. Video files were recorded onto the tablet hard drive.

FLIR 650sc

The 650sc camera has built in battery and screen for a live video display. Video was recorded in 10 minute long segments for the duration of each survey. Video files were recorded onto an SD card.

Bat detectors

3.17 The automated bat detectors used during the flight-line corridor surveys were Wildlife Acoustics Song Meter 4 (SM4BAT FS) bat detectors. These are 16-bit full-spectrum bat detectors with internal storage and computing power that allows the unit to be used as a remote fixed-point detector. Recording is triggered by ultrasound, such as bat calls, in the vicinity of the detector, and any bat calls are stored as sound files on an internal SD card.

3.18 The detectors were placed in water-proof boxes connected by a 10 m cable to an omnidirectional Wildlife Acoustics SMM-U1 microphone. The microphones were attached to a telescopic pole at 3-4 m above ground level, and angled at 45° to the ground to allow water to run off, as recommended by the manufacturers.

3.19 All surveyors used a Batbox Duet detector for listening to bat calls from the combined heterodyne/frequency division output bat detector on each survey to supplement visual observations.

Data analysis

3.20 Full details of the bat call data analysis methods are provided in Appendix 2.

3.21 Records of lesser horseshoe bats from three sources (surveyor, automated bat detector and TI camera) were combined into a single database and duplicates removed, where possible, to give a minimum and maximum count of bats passing through the survey corridor. Each bat that was observed or recorded on the TI camera (if not observed by the surveyor) was identified to species (if this was not possible in the field) by referring to the echolocation calls recorded by automated detectors at the time of the observation. If a bat was recorded on the TI camera but its identity could not be corroborated by either surveyor or bat detector (or both) the record was not used in the analysis. Records of species other than lesser horseshoe bats were removed from the dataset and analysed separately. For these surveys, no other significant commuting behaviour was observed for any species other than lesser horseshoe bat and the analysis for other species only uses data from the automated bat detectors located within each SC.

Automated survey

Selection of survey locations

3.22 Surveys were undertaken in two woodland areas (eastern and western) identified by FoDDC as potential woodland mitigation areas. Three locations were chosen within each area of woodland. Locations were chosen, where possible, to match the following criteria:

- They are at least 30 m apart from each other.
- They are at habitat interfaces where high levels of bat activity would be expected, e.g. at the woodland edge, near wet areas, at tracks or rides, or on known/suspected commuting routes.
- They are away from areas of high public use, to prevent theft of equipment.

3.23 Figure 2 shows the extent of the automated survey area and the locations where bat detectors were deployed within that area. Photographs of each automated survey location are provided in Section 8 (Photographs 4-9).

3.24 The grid reference of each location is included below:

- 1A – SO 63919 15615
- 1B – SO 63989 15590
- 1C – SO 63892 15531
- 2A – SO 64482 15677
- 2B – SO 64515 15717
- 2C – SO 64480 15751

3.25 A brief description of each of the six locations is given below:

Western woodland survey area

1) Automated location 1A is near the northern edge of the western woodland survey area, which largely consists of a block of coniferous plantation. The location is ca. 50 m south-east of a purpose built bat roost that supports a large breeding colony of lesser horseshoe bats. To the north there is a ca. 10 m wide ride that separates the survey area from woodland to the north of the ride.
2) Automated location 1B is ca. 75 m east-south-east of 1A at the north-east corner of the same block of coniferous plantation and on the edge of the same ride to the north. To the east, there is deciduous woodland and a footpath.
3) Automated location 1C is close to the southern edge of the western survey area and on the edge of the coniferous plantation, where it abuts an area of scrub and mature trees to the north of a small road. At the survey location there is a clear gap between coniferous trees where the vegetation is otherwise dense.

Eastern woodland survey area

4) Automated location 2A is the most southerly of the three eastern locations and in open, mixed woodland with a relatively open canopy. There is a chain of small woodland pools ca 30 m east of the location.
5) Automated location 2B is close to the eastern boundary of the eastern survey area in open, mixed woodland on a fenceline that runs roughly north-south. The location is on the edge of a wet area with small pools to the south.
6) Automated location 2C is on the edge of a public footpath that runs along the northern boundary of the eastern survey area. The footpath forms a narrow ride through the woodland.

General methods

3.26 Automated bat detector surveys were undertaken using Wildlife Acoustics Song Meter 4 (SM4BAT FS) bat detectors, as for the flight-line corridor surveys.

3.27 The detectors were deployed for five nights at each of the locations. The original intention was to deploy detectors monthly during May-August 2016 but it was not possible to deploy detectors until early June, as the survey area was not confirmed until then. Detectors were deployed twice (early and late) in June with the early June deployment intended as a proxy for May. Detectors were also deployed for five nights in July and August.

3.28 The detectors were set to monitor during the period when bats are active outside of their roosts. They were programmed to begin recording from half an hour before sunset until half an hour after sunrise. Survey hours varied throughout the survey season according to daylight hours and have been calculated for each recording session in order to accurately calculate activity indices.

Bat call data analysis

3.29 Full details of the bat call data analysis methods are provided in Appendix 2.

Limitations to methods

3.30 It was not always possible to correlate records from surveyors, bat detectors and TI camera video, and therefore remove duplicates. There are various reasons for this (described below) and these limitations mean that it is not possible to provide a definitive count of commuting lesser horseshoe bats across each SC during each survey.

- At SC1 and SC3 in particular, lesser horseshoe bats often commuted through narrow gaps in vegetation at the far end of the SCs (at the southern end of SC1 and both ends of SC3). As such, bats were difficult to observe as they were obscured, flying behind observers, and/or out of the field of view of the TI camera. In the case of SC1 and SC3 the use of the TI camera did not add significant value to the survey as most of the commuting lesser horseshoe bats were not recorded by the TI camera.
- Calculating the exact time of a bat pass was only possible with bat detector recordings. It was possible for surveyors to record bat passes within a few seconds accuracy and this level of accuracy was also achievable with the TI camera. As a result, and given that there was always a margin for error, it was not always possible to correlate a bat recorded using any of the methods with those recorded using the other methods.
- The A35 camera is not of high enough resolution to be able to use the video output during the survey to supplement the surveyor’s naked eye observations, as it was possible to do with the T650sc camera. At SC 2, where the T650sc camera was used for the final two surveys, the camera significantly increased the number of bats recorded by the surveyor during the surveys.
- The TI camera at SC2 on 23 May malfunctioned and did not record usable video data

3.31 Overall, as the data in Table 8 in Appendix 3 shows, the minimum and maximum counts for each survey (and each SC) did not show great variation. It was possible, in most cases, to ascertain how many bats crossed each SC by combining the datasets. It is considered, as a result, that the counts recorded (using three methods) are robust and can be relied upon.

3.32 The weather was not optimal on 14 and 28 June when intermittent light rain was recorded. This may have suppressed bat activity to some extent but the pattern of overall activity increasing gradually throughout the surveys does not appear to have been affected by adverse weather conditions during these surveys.

4 Results

Flight-line corridor surveys

4.1 Details of flight-line corridor surveys (survey dates, surveyors, weather conditions) are included in Table 7 in Appendix 3.

Lesser horseshoe bats

Count data

4.2 Table 1 below gives minimum and maximum counts, mean and standard deviation of lesser horseshoe bat counts at each SC, according to survey period.

4.3 Table 8 in Appendix 3 gives a breakdown of counts of lesser horseshoe bats taken from each surveyor, detector and TI camera for each survey and each SC. Where bats were recorded by more than one method duplicates were removed. The minimum and maximum counts reflect where it was not possible to match records between different methods and be sure about how many bats had crossed the SC.

4.4 Graph 1 below shows the minimum lesser horseshoe bat count for each SC during each survey, as well as the average count across all SCs.

4.5 Table 1 and Graph 1 show that initially, before an increase in counts from SC 2 in August, numbers of lesser horseshoe bats recorded crossing each survey corridor were relatively consistent across SCs and across each survey. The total count range across all surveys and all SCs was 321-363 bats with the minimum count (n = 321) averaging 53.5 ± 22.6 bats per survey. The highest minimum count was 90 bats in August with a low of 28 bats during the first June survey.

4.6 At SC 1, the total count range across all surveys was 64-69 bats with the minimum count (n = 64) averaging 10.7 ± 5.8 bats per survey. The highest minimum count was 18 bats in August with a low of one bat during the first June survey. The counts appear to confirm the presence of a minor commuting route on flyway 4.

4.7 At SC 2, the total count range across all surveys was 122-153 bats with the minimum count (n = 122) averaging 20.3 ± 20.4 bats per survey. The highest minimum count was 60 bats in August with a low of five bats during the second June survey. Counts at SC 2a (surveys 1-4) were much lower than SC 2b (surveys 5-6) averaging 10.3 bats and 40.5 bats respectively. The counts appear to confirm the presence of a major commuting route on flyway 1.

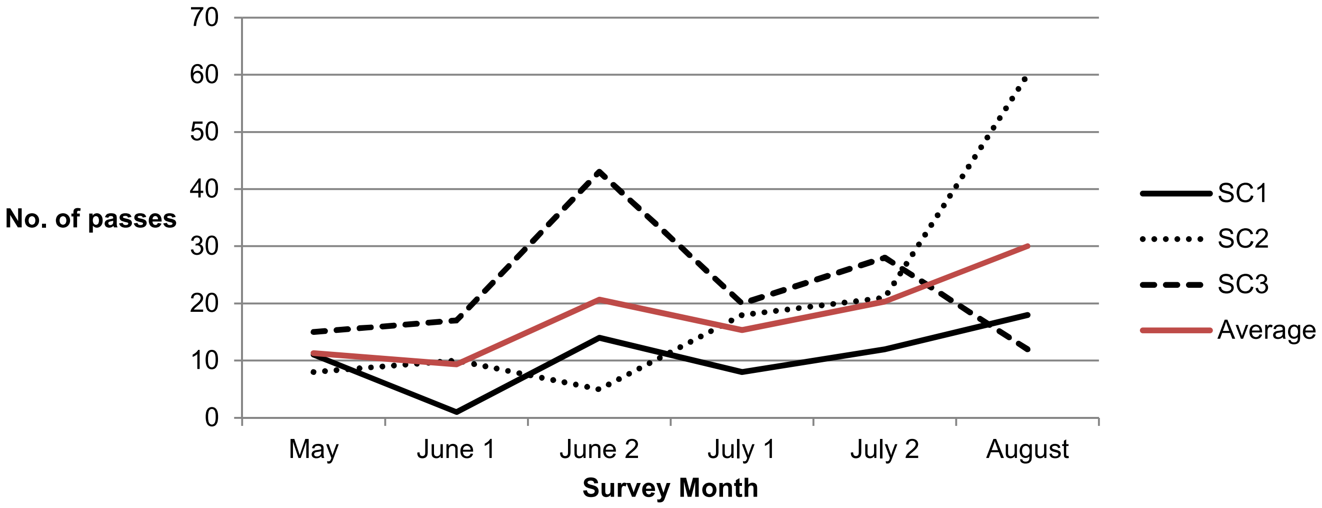
4.8 At SC3, the total count range across all surveys was 135-141 bats with the minimum count (n = 135) averaging 22.5 ± 11.4 bats per survey. The highest minimum count was 43 bats in late June with a low of 12 bats during the first August survey. The counts appear to confirm the presence of a major commuting route on flyway 2.

4.9 The TI camera data was not used when a bat was recorded using this method but no other, as there was no way of confirming the species of bat without a time-correlated bat call file. A total of 121 bat passes were detected by the TI cameras alone without any of the other methods recording bats, but the species could not be confirmed. 18 lesser horseshoe bat records were recorded by the TI camera and a detector and not the surveyor, which is 5.6 % of the minimum count.

Table 1: Minimum and maximum counts, mean and standard deviation of lesser horseshoe bat counts at each SC, according to survey month.

	SC1		SC2		SC3		Total		Average		St Dev	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
May	11	11	8	8	15	16	34	35	11.3	11.7	4.0	4.0
June 1	1	1	10	10	17	17	28	28	9.3	9.3	8.0	8.0
June 2	14	14	5	5	43	44	62	63	20.7	21.0	20.4	20.4
July 1	8	8	18	18	20	21	46	47	15.3	15.7	6.8	6.8
July 2	12	15	21	37	28	30	61	82	20.3	27.3	11.2	11.2
August	18	20	60	75	12	13	90	108	30.0	36.0	34.0	34.0
Grand Total	**64**	**69**	**122**	**153**	**135**	**141**	**321**	**363**	**107.0**	**121.0**	**45.4**	**45.4**
Mean	10.7	11.5	20.3	25.5	22.5	23.5	53.5	60.5				
Standard Deviation	5.8	6.5	20.4	26.9	11.4	11.6	22.6	30.4				

Graph 1: Minimum lesser horseshoe bat counts at each SC, according to survey month.



Behaviour and key flight-lines

4.10 Graph 2 below shows proportions of total surveyor counts that were assigned one of three categories: 'out' (commuting away from the roost), 'back' (commuting towards the roost) and 'heard not seen' (heard on surveyor's bat detector), in relation to survey period. A total of 13 records were recorded by detectors and 'seen' by TI cameras but not surveyors and these have been added to the 'out' and 'back' totals. Bats that were recorded by bat detectors but not surveyors or TI cameras make up the totals. Graph 3 shows this proportion in relation to SC.

4.11 Overall 52.6 % of the total number (n = 169) of lesser horseshoe bats recorded and 85.4 % of the number (n = 183) that were seen (by surveyor or TI camera) were commuting away from the roost ('out'). Only 9 % of the total (n = 29) with 14.6 % of those that were seen were commuting 'back' towards the roost. Of the total count, 61.7 % of those recorded were seen, with 22.4 % heard by the surveyor on a heterodyne detector but not recorded by an automated detector, and 15.9 % were only recorded by an automated detector.

Survey Corridor 1

4.12 At SC 1, 50 % of the total number (n = 32) recorded and 78 % of the number (n = 41) that were seen were 'out' with 14.1 % of the total number (n = 9) recorded and 22 % that were seen were 'back'.

4.13 At SC 1, most (n = 46; 77 %) of the bats recorded by surveyors were recorded by S2 (see Figure 1) at the southern end of the SC. At the southern end there was a clear commuting route through dense vegetation, with bats usually flying very close (sometimes behind) the surveyor. Numbers crossing the SC at this point were variable with peaks of 14 on 28 June and 13 on 9 August but with just one bat and three bats on 14 June and 18 July respectively.

Survey Corridor 2

4.14 At SC 2, 53.3 % of the total number (n = 65) of lesser horseshoe bats recorded and 82.3 % of the number (n = 79) that were seen were 'out' with 11.5 % of the total number (n = 14) recorded and 17.7 % that were seen were 'back'.

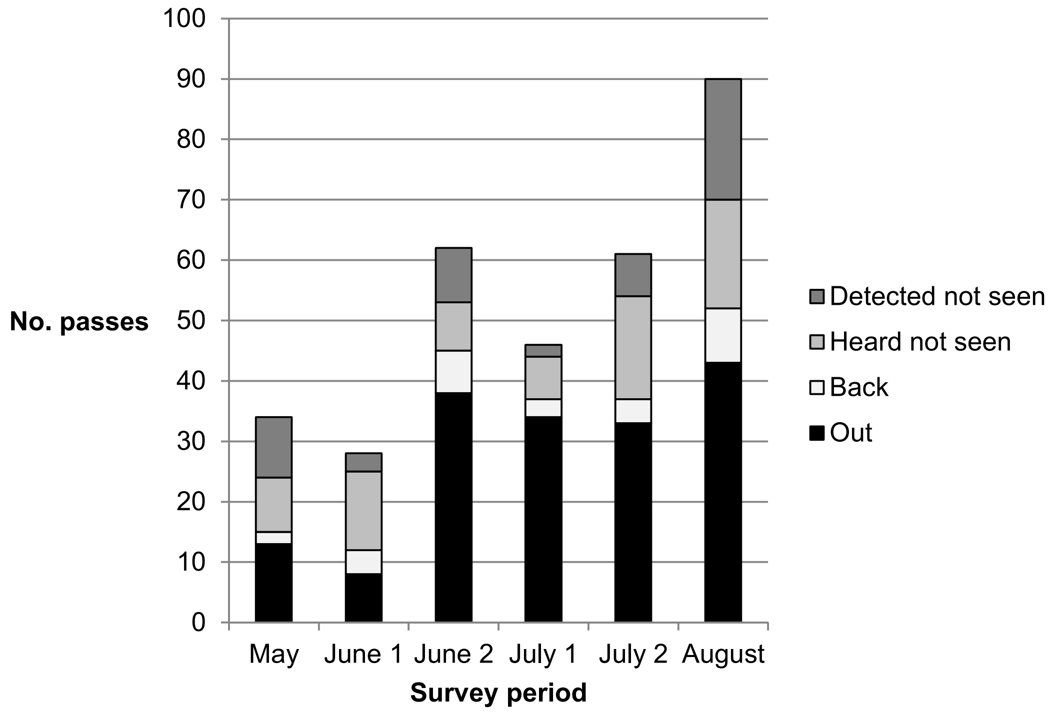
4.15 At SC 2, numbers of commuting bats were variable until July when a clear commuting route was detected across the road to the east. The SC location (as well as surveyor and detector locations) was changed to reflect this. At this point, 17 bats were recorded crossing on 5 July, with 12 on 18 July and 33 on 9 August. At this point bats were flying across the narrowest break between the vegetation on either side of the road

Survey Corridor 3

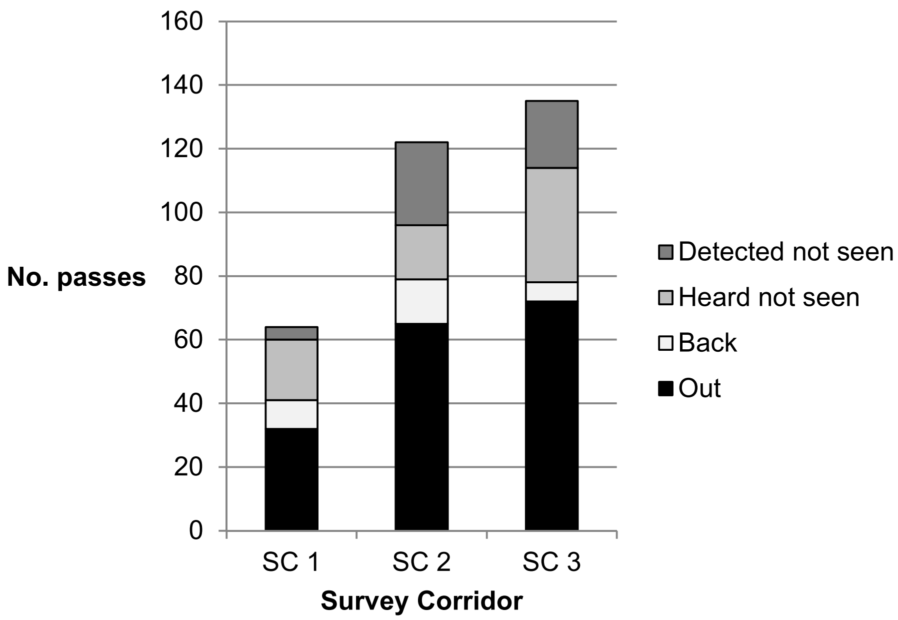
4.16 At SC 3, 53.3 % of the total number (n = 72) of lesser horseshoe bats recorded and 92.3 % of the number (n = 38) that were seen were 'out' with 4.4 % of the total number (n = 6) recorded and 7.7 % that were seen were 'back'.

4.17 At SC 3 there were two clear commuting corridors, both following vegetation corridors at either end of the SC, with 37.5 % and 62.5 % of the bats recorded at the western and eastern ends of the SC respectively. At the western end there was a clear commuting route through dense vegetation, with bats usually flying very close (sometimes behind) the surveyor. At the eastern end bats appeared to be following a narrow divide (forming a ride) between blocks of coniferous and broad-leaved woodland and flying very close to the surveyor. Very few bats were seen to fly across the more open clearing that makes up the majority of SC3.

Graph 2: Lesser horseshoe bat commuting direction by survey period.



Graph 3: Lesser horseshoe bat commuting direction by SC.



Other species

4.18 Table 2 below gives the number of passes recorded for species other than lesser horseshoe bat during the flight-line corridor surveys. The counts are taken from both detectors at each SC. Overall, the species assemblage is similar to the automated survey data (see below), although the proportion of the total number of passes is higher for most species in relation to common pipistrelle bat (see Table 5).

Table 2: Number of bat passes (B) and percentage of total for species other than lesser horseshoe bat.

		% of total	
Species	**B**	**Flight-line**	**Automated**
Greater horseshoe bat	11	1.0	0.2
Common pipistrelle	683	61.2	83.4
Common / Soprano pipistrelle	5	0.4	0.2
Soprano pipistrelle	149	13.4	4.8
Common / Nathusius' pipistrelle	14	1.3	1.6
Nathusius' pipistrelle	10	0.9	0.9
Noctule	30	2.7	0.2
Noctule / Leisler's bat	2	0.2	<0.1
Long eared bat sp.	3	0.3	0.2
Myotis species	55	4.9	2.6
Barbastelle bat	10	0.9	0.2
Total	**58**		

Automated survey

4.19 Automated bat detectors were operating for a total of 120 nights, equating to 962 hours and 22 minutes of survey time between May and August 2016. Table 3 gives details of automated bat detector deployment dates and locations with the latter illustrated in Figure 2, as well as average relative activity recorded for lesser horseshoe bats at each location. Table 4 gives details of the number of passes and relative activity of all bats recorded during automated detector surveys.

4.20 Bat passes per hour (B/h) are used as the unit of relative activity in this report. For the definition of B and B/h used in this analysis see Appendix 2.

Table 3: Numbers and deployment dates of automated detectors.

Location	June (1)	June (2)	July	August
A1A	10-15/06	21-25/06	19-24/07	11-15/08
A1B	03-07/06	21-25/06	19-24/07	11-15/08
A1C	03-07/06	21-25/06	19-24/07	11-15/08
A2A	03-07/06	21-25/06	19-24/07	11-15/08
A2B	03-07/06	21-25/06	19-24/07	11-15/08
A2C	03-07/06	21-25/06	19-24/07	11-15/08

Table 4: Number of bat passes (B) and relative activity (B/h) at automated detector locations.

Location	B	B/h
A1A	414	2.6
A1B	1972	12.3
A1C	639	4
A2A	4275	26.6
A2B	7015	43.7
A2C	1684	10.8
Total	**15999**	**16.7**

Relative activity of bats

4.21 A total of 15,999 passes from at least eleven species of bat were recorded. The overall activity rate (16.7 B/h) was high in comparison to other comparable data collected by BSG Ecology at 49 other sites across England, Wales and Scotland[1].These species included lesser horseshoe bat, greater horseshoe bat *Rhinolophus ferruquinum*, common pipistrelle *Pipistrellus pipistrellus*, soprano pipistrelle *Pipistrellus pygmaeus*, Nathusius' pipistrelle *Pipistrellus nathusii*, noctule *Nyctalus noctula*, Leisler's bat *Nyctalus leislerii*, serotine *Eptesicus serotinus*, barbastelle *Barbastellus barbastella*, long-eared bat *Plecotus* sp., and *Myotis* sp. The relative activity of bat species recorded at all detector locations is recorded in Table 5.

4.22 Recording eleven species of bats is not considered to be unusual bearing in mind the type and quality of habitats locally and in the wider area. The relatively high recorded activity rate indicates the quality of the habitat in the area for a wide range of bat species and gives confidence that the survey has robustly captured bat activity in the areas.

4.23 Across the survey season, the highest relative activity rate recorded was for common pipistrelle, at an average of 13.9 B/h (B = 13,340) followed by lesser horseshoe bat (0.9 B/h; B = 900; 5.6 % of total) and soprano pipistrelle (0.8 B/h; B = 761) with 90.8% of all the recorded passes identified as bats from the Pipistrellus genus. The next most frequently recorded species were *Myotis* sp. with 0.4 B/h (B = 414; 2.6 % of total) with Nathusius' pipistrelle next most frequent (0.1 B/h; B = 136; 0.9 % of total. No other species made up more than 0.2 % of the total number of bat passes recorded. There were also 39 long-eared bat *Plecotus* sp. passes recorded, with 37 passes for barbastelle, 33 for noctule, 30 for greater horseshoe bat, four for serotine and two for Leisler's bat.

Table 5: Relative activity (B/h) at automated detector locations

Species	Detector relative activity (B/h)						Total		
	A1A	A1B	A1C	A2A	A2B	A2C	B	B/h	%
Lesser horseshoe bat	1.3	0.6	2.9	0.1	0.2	0.5	900	0.9	5.6
Greater horseshoe bat	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	30	<0.1	0.2
Common pipistrelle	0.6	9.6	0.5	24.8	38.4	9.2	13340	13.9	83.4
Common / soprano pipistrelle	0.1	<0.1		0.1	<0.1	<0.1	29	<0.1	0.2
Soprano pipistrelle	0.5	1.1	0.1	0.4	2.4	0.2	761	0.8	4.8
Common / Nathusius' pipistrelle		0.1	0.2	0.3	0.9	0.1	262	0.3	1.6
Nathusius' pipistrelle		<0.1		0.3	0.5	<0.1	136	0.1	0.9
Noctule	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	33	<0.1	0.2
Noctule / Leisler's bat	<0.1		<0.1	<0.1			4	<0.1	<0.1
Leisler's bat		<0.1					2	<0.1	<0.1
Serotine		<0.1		<0.1	<0.1		4	<0.1	<0.1
Serotine / Leisler's bat				<0.1			1	<0.1	<0.1
Eptesicus / Nyctalus		<0.1	<0.1				3	<0.1	<0.1
Barbastelle bat		0.2			0.1		37	<0.1	0.2
Long eared bat sp.		0.1		<0.1	0.1	<0.1	39	<0.1	0.2
Myotis / long-eared bat sp.				<0.1			4	<0.1	<0.1
Myotis species	0.1	0.4	0.1	0.5	1.0	0.5	414	0.4	2.6
Grand Total	**2.6**	**12.3**	**4.0**	**26.6**	**43.7**	**10.8**	**15999**	**16.7**	

4.24 The data in Table 6 indicate that overall bat activity was low in early June (5.5 B/h) peaked in late June (34.1 B/h) and then dropped in July (13.3 B/h) and August (14.6 B/h). All species for which

[1] Based on this activity rate falling into the highest third of activity rates from results from similar automated surveys carried out by BSG at 49 locations in England, Wales and Scotland (BSG Ecology, 2015).

sufficient data were recorded had a low in activity in early June with peak activity in either late June (Nathusius' and soprano pipistrelles) or August (lesser horseshoe bat and *Myotis* sp.).

Table 6: Relative activity (B/h) of bat species in relation to survey period.

	B/h				
Species	**June (1)**	**June (2)**	**July**	**August**	**Total**
Lesser horseshoe bat	0.4	1.1	0.8	1.3	0.9
Greater horseshoe bat	<0.1	<0.1	<0.1	<0.1	<0.1
Common pipistrelle	4.5	29.2	11.4	11.4	13.9
Soprano pipistrelle	0.2	1.7	0.3	1.0	0.8
Nathusius' pipistrelle	<0.1	0.6	<0.1	<0.1	0.1
Noctule	<0.1	<0.1	0.1	<0.1	<0.1
Leisler's bat		<0.1	<0.1		<0.1
Serotine		<0.1	<0.1		<0.1
Barbastelle bat		<0.1	<0.1	0.1	<0.1
Long eared bat sp.	<0.1	<0.1	0.1	0.1	<0.1
Myotis species	0.2	0.4	0.4	0.7	0.4
Total (all bats)	**5.5**	**34.1**	**13.3**	**14.6**	**16.3**

Distribution of bats

Lesser horseshoe bat

4.25 Lesser horseshoe bats were recorded at all of the automated detector locations and from all 24 automated detector deployments. In general the activity level (0.9 B/h) was high in comparison to other data collected by BSG Ecology; however, comparable data were only available for eight sites and a high activity rate is not surprising given the proximity of automated detector locations to a large breeding colony[2].

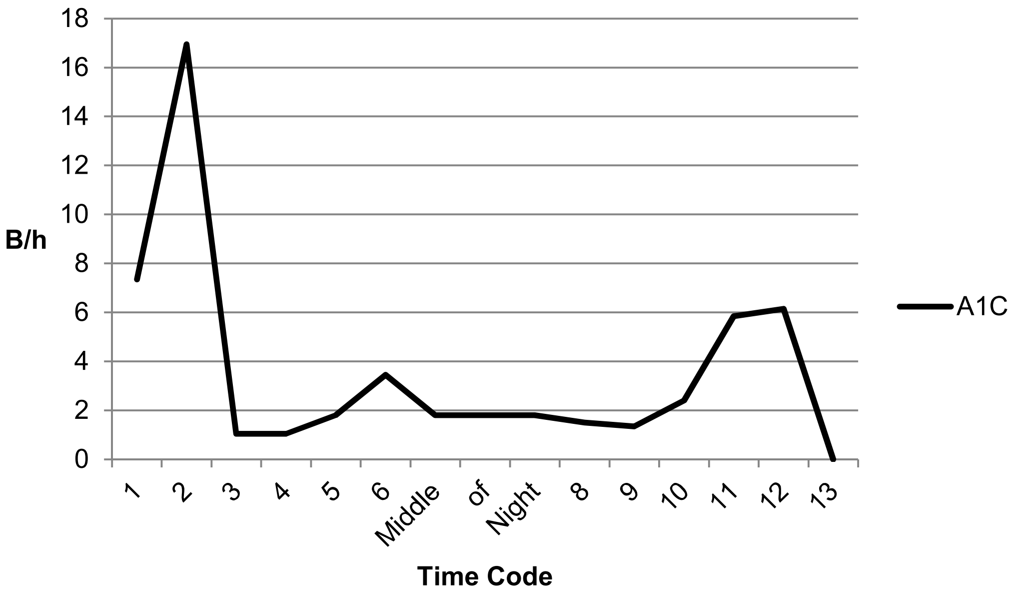
4.26 Higher levels of activity were recorded in the western woodland survey area compared to the eastern (1.6 B/h and 0.3 B/h respectively). The highest rate of activity was recorded at A1C (2.9 B/h) which is located close to the commuting route (flyway 1) that crosses SC2 and it is likely that bats are commuting through the coniferous woodland from the roost and then funnelling through this gap in the southern end of the wood before making their way across the road. Activity was also fairly high at A1A at the northern end of the wood (1.3 B/h) and reduced to the east at A1B (0.6 B/h). In the eastern woodland, activity was highest along the public footpath at A2C (0.5 B/h) but fairly low at the other two locations, A2A (0.1 B/h) and A2B (0.2 B/h).

4.27 The nocturnal activity patterns showed that passes were typically being recorded first by detectors within 20 minutes of sunset, with 69 records (mostly from locations A1A and A1C) during this time period (Time Code[3] (TC) 1; 1.6 B/h). The peak in activity was during 20-40 minutes after sunset (TC2; 3.9 B/h). Although there was some variation between locations, activity then dropped off and remained at fairly low levels for most of the night before increasing again close to dawn, at 60-40 minutes before sunrise (TC 11; 1.4 B/h) and 40-20 minutes before sunrise (TC12; 1.6 B/h). Although this is a relatively typical pattern of bat activity for many species of bats, with peaks in activity often recorded early and late in the night, when bats are likely to need to feed most urgently the timing of the peaks close to sunset and sunrise (for a species that emerges quite late from roosts) indicates that the detectors are close to the roost and likely to be on commuting routes.

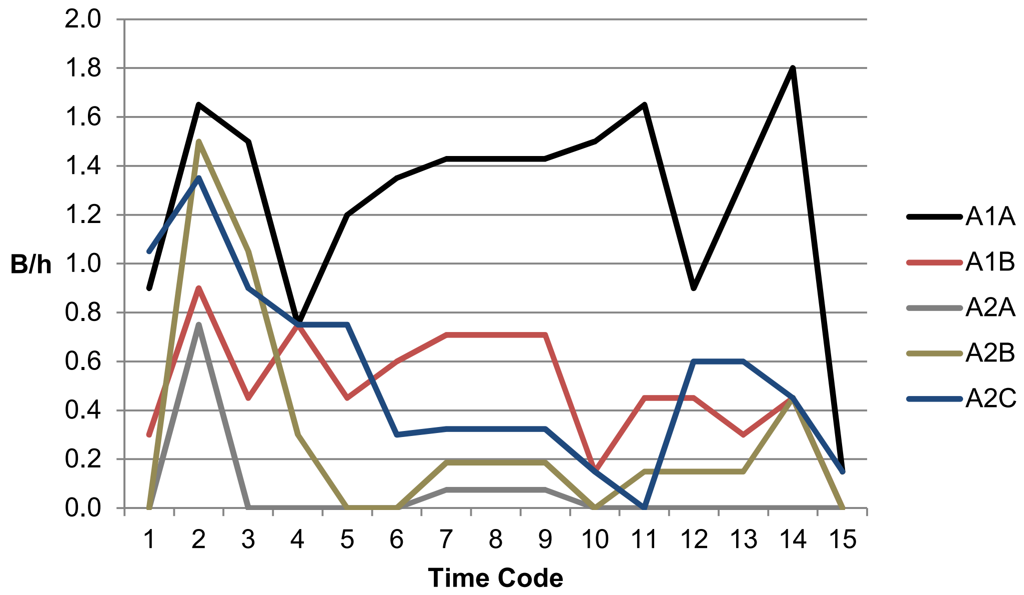
4.28 Graph 2 below shows lesser horseshoe bat activity in relation to time of night for A1C, where the highest activity levels were recorded. Graph 3 shows the same data for the other locations as well the average activity levels. Note that the x-axis scale for each graph is substantially different.

[2] Based on this activity rate being the highest recorded from similar surveys carried out by BSG at eight locations in England and Wales, where this species was recorded (BSG Ecology, 2015).
[3] The Time Code categories place bat calls in categories in relation to their proximity to sunset or sunrise. For a full explanation see Appendix 2.

Graph 2: Relative activity (B/h) of lesser horseshoe bat in relation to time of night at A1C.



Graph 3: Relative activity (B/h) of lesser horseshoe bat in relation to time of night at all other locations.



Common pipistrelle

4.29 Common pipistrelle was recorded at all of the automated detector locations and from all 24 automated detector deployments. In general the activity level (13.9 B/h) was high in comparison to other comparable data collected by BSG Ecology at 51 other sites across England, Wales and Scotland[4].

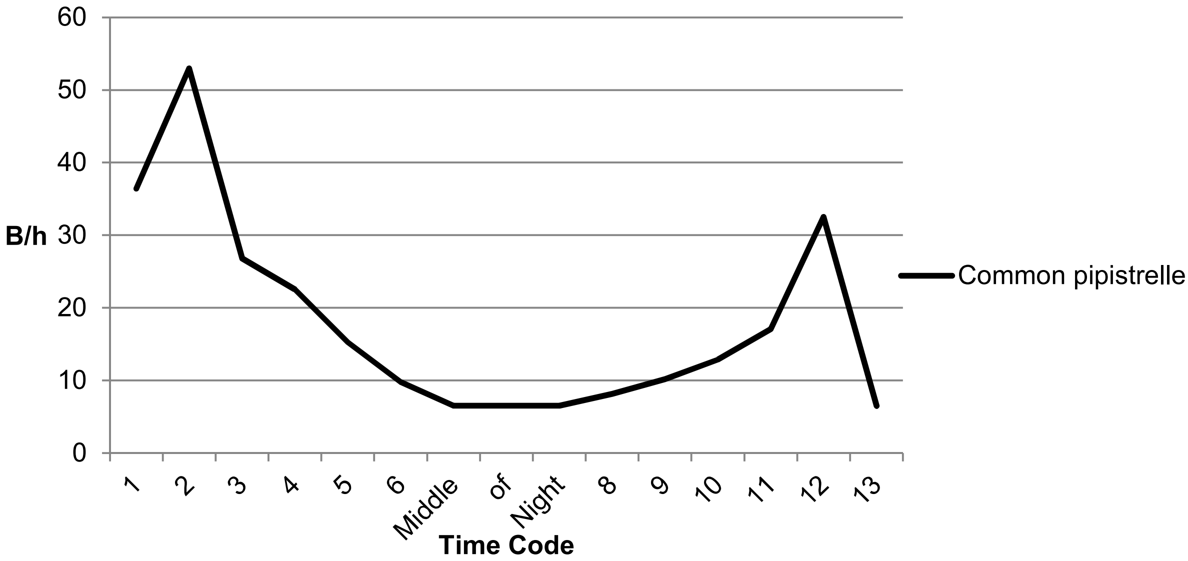
[4] Based on this activity rate falling into the highest third of activity rates from results from similar surveys carried out by BSG at 51 locations in England, Wales and Scotland, where this species was recorded (BSG Ecology, 2015).

4.30 Much higher levels of activity were recorded in the eastern woodland survey area compared to the western (24.1 B/h and 3.6 B/h respectively). The highest rate of activity was recorded at A2B (38.4 B/h) with 24.8 B/h recorded at A2A both of which are located in open mixed woodland close to a series of small ponds. It is likely that these bats were foraging over the canopy of the woodland in this area. Activity at other locations was lower although 9.6 B/h was recorded along the open ride at A1B.

4.31 The nocturnal activity patterns showed that a reasonably high number of passes were recorded before sunset (TC 0; B = 137) and that activity levels rapidly increase within 20 minutes of sunset (TC 1; 36.4 B/h) to a peak 20-40 minutes after sunset (TC 2; 53 B/h). Activity then declined steadily to a low in the middle of the night period (TC 7; 6.5 B/h) before returning to a second peak in the hour before sunset, particularly 40-20 minutes before sunrise (TC 12; 36.6 B/h). This pattern of activity indicates that bats are roosting nearby and that the eastern survey area (particularly) is likely to be of particular importance for foraging both early and late in the night.

4.32 Graph 4 below shows common pipistrelle bat activity in relation to time of night.

Graph 4: Relative activity (B/h) of common pipistrelle in relation to time of night at all locations.



Soprano pipistrelle

4.33 Soprano pipistrelle was recorded at all of the automated detector locations and from all 24 automated detector deployments. In general the activity level (0.8 B/h) was much lower than for common pipistrelle and was low in comparison to other comparable data collected by BSG Ecology at 51 other sites across England, Wales and Scotland[5].

4.34 Slightly higher levels of activity were recorded in the eastern woodland survey area compared to the western (1.0 B/h and 0.6 B/h respectively). The highest rate of activity was recorded at A2B (2.4 B/h).

4.35 The nocturnal activity patterns were more erratic than common pipistrelle showed that a few passes were recorded before sunset (TC 0; B = 13) and that activity levels increased to an early peak 20-40 minutes after sunset (TC 2; 1.4 B/h). Activity then declined a little and surprisingly peaked 120-100 minutes before sunrise (TC 8; 1.7 B/h) before dropping again. The levels of activity do not indicate that this area is of particular importance to the species although it is likely that small numbers are roosting nearby.

[5] Based on this activity rate falling into the lowest third of activity rates from results from similar surveys carried out by BSG at 51 locations in England, Wales and Scotland, where this species was recorded (BSG Ecology, 2015).

Nathusius' pipistrelle

4.36 Nathusius' pipistrelle was recorded at three of the automated detector locations (A1B, 2A, A2B) and from seven automated detector deployments. The activity level for (0.1 B/h) was low and was low in comparison to other comparable data collected by BSG Ecology at 34 other sites across England, Wales and Scotland[6].

4.37 Higher levels of activity were recorded at A2A (0.3 B/h) and A2B (0.5 B/h) with the majority of activity recorded in late June (B = 124; 92 % of total). A late peak in activity levels close to sunrise (TC 13; 1.1 B/h) was recorded with most passes recorded from what is assumed to be one or two bats repeatedly recorded on the morning of 23 June at A2B. These bats are likely to have roosted close to the detector location.

Myotis sp.

4.38 *Myotis* sp. was recorded at all of the automated detector locations except A1A and from 19 automated detector deployments. The activity level (0.4 B/h) was low in comparison to other comparable data collected by BSG Ecology at 50 other sites across England, Wales and Scotland[7].

4.39 A higher level of activity were recorded at A2B (1 B/h). There was an early peak in activity from A2A (TC2; 1.5 B/h) and A2B (2.4 B/h) which may suggest a roost nearby. Activity remained fairly consistent throughout the night before declining after 40 minutes before sunrise.

Other species of bat

4.40 Greater horseshoe bat was recorded from all detector locations and from 16 deployments, which is surprising given that only 30 passes of this species were recorded. No more than four passes were recorded from any of the deployments and this species was irregularly recorded throughout the survey period. The earliest record was 57 minutes after sunset with the latest 67 minutes before sunrise.

4.41 Noctule was recorded from 11 deployments (B = 31), which is a very low activity rate for a relatively common species of bat. No more than nine passes were recorded from any of the deployments with most passes (B = 16) recorded from the open ride at A1B. The earliest record was 14 minutes after sunset with the latest 25 minutes before sunrise.

4.42 Leisler's bat was recorded on two occasions, both at A1B on 25 June three minutes after sunrise (presumably roosting nearby) and on 22 July.

4.43 Serotine was recorded on four occasions, at A1B (2), A2A and A2B. All records were in late June and July and none were within an hour of sunset or sunrise.

4.44 Long-eared bat sp. was recorded from four locations (A1B, A2A, A2B, A2C) and from nine deployments. The highest number of passes from a single location was at A1B (18). The earliest record was 29 minutes after sunset with the latest 75 minutes before sunrise.

4.45 Barbastelle was recorded from two locations (A1B, A2B) and from six deployments. The majority of passes were recorded from A1B (B = 28; 76 % of total) with 19 of those in August. The earliest record was 33 minutes after sunset with the latest 42 minutes before sunrise.

[6] Based on this activity rate falling into the lowest third of activity rates from results from similar surveys carried out by BSG at 51 locations in England, Wales and Scotland, where this species was recorded (BSG Ecology, 2015).
[7] Based on this activity rate falling into the lowest third of activity rates from results from similar surveys carried out by BSG at 51 locations in England, Wales and Scotland, where this species was recorded (BSG Ecology, 2015).

5 References

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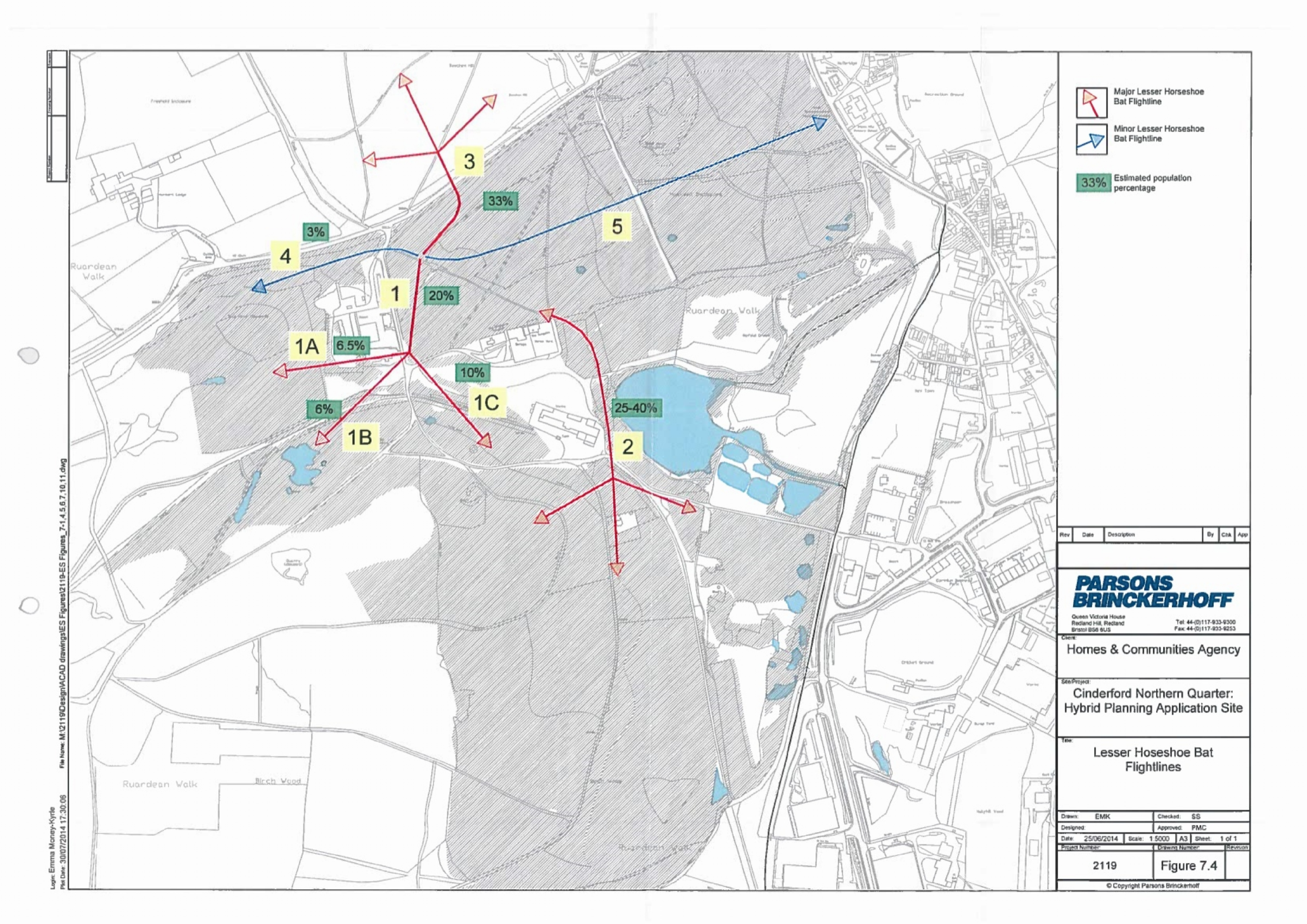
6 Appendices

(overleaf)

Appendix 1 – Flight line map



Appendix 2 – Bat call analysis methods

Bat call identification

Recorded bat calls were converted from full spectrum recordings to zero-crossing data files using Wildlife Acoustics Kaleidoscope Pro Software (Version 3.1.4B, 2015). The software uses predefined classifiers to apply a species label to each bat call file[8]. The calls were then analysed again by an experienced surveyor using AnalookW software (Titley electronics, Version 3.8m, 2010) to confirm the species labels, and amend them, where necessary.

For species of long-eared bats records were not identified to species level due to the overlapping call parameters of each species but were assumed to refer to brown long-eared bats. It is possible that grey long-eared bat (*Plecotus austriacus*) occurs in the survey area, given the species' known distribution, but it is likely that most if not all records refer to brown long-eared bat, given their abundance (Harris & Yalden, 2008). Species of the genus *Myotis* were grouped together as many of the species have overlapping call parameters, making species identification problematic (Hundt, 2012).

For pipistrelle species the following criteria, based on measurements of peak frequency, were used to classify calls:

Common pipistrelle	≥42 and <49 kHz
Soprano pipistrelle	≥51 kHz
Nathusius' pipistrelle	<40 kHz
Common pipistrelle / Soprano pipistrelle	≥49 and <51 kHz
Common pipistrelle / Nathusius' pipistrelle	≥40 and <42 kHz

Bat calls which could not be ascribed to any of these categories were not used in the analysis.

Calculation of relative activity

The SM4 detectors were configured to record above the level of ambient noise, such as from wind or rain, and set to define a bat pass (B) as a call note of > 2 ms which is separated from another by more than one second.

AnalookW software was used for all analysis of bat calls. It enables analysis of the relative activity of different species of bats by counting the number of bat passes (B) recorded within a unit of time – hour (h) was used. More than one pass of the same species was counted within a sound file if multiple bats were recorded calling simultaneously. During analysis of sound files, it was possible to estimate the minimum number of bats recorded on individual sound files but not whether consecutive sound files had recorded, for example, a number of individual bats passing as they commute to a feeding habitat or one bat calling repeatedly as it flies up and down the edge of forestry. Although relative abundance cannot be estimated from this analysis, the number of bat passes does reflect the relative importance of a feature/habitat to bats by assigning a level of bat activity that is associated with that feature, regardless of the type of activity.

[8]For more information on how Wildlife Acoustics Kaleidoscope Pro Software classifies bat calls please see: https://www.wildlifeacoustics.com/products/kaleidoscope-software-ultrasonic

Analysis by sunset-sunrise times

As part of the analysis of nocturnal patterns of behaviour for bats the data were split into discrete time periods relating to their proximity to sunset or sunrise. The time categories (time codes: TC) were as follows:

TC 0 = before sunset

TC 1 = 0-20 min after sunset

TC 2 = 20-40 min after sunset

TC 3 = 40-60 min after sunset

TC 4 = 60-80 min after sunset

TC 5 = 80-100 min after sunset

TC 6 = 100-120 min after sunset

TC 7 = Middle of night (varies across seasons)

TC 8 = 120-100 min before sunrise

TC 9 = 100-80 min before sunrise

TC 10 = 80-60 min before sunrise

TC 11 = 60-40 min before sunrise

TC 12 = 40-20 min before sunrise

TC 13 = 20-0 min before sunrise

For each of these categories B/h was calculated to allow a comparison between the activity level recorded in different time periods and TC 7 was corrected to allow for variation in night length throughout the survey season.

Appendix 3 – Bat survey results

Table 7: Details of flight-line corridor surveys. RT = Rachel Taylor; AK = Anton Kattan, RP = Robert Pelc, HB = Hannah Bilston, VA = Vilas Anthwal, LM = Luke Metcalf, AG = Anna Gundrey, MH = Matthew Hobbs, GL = Gareth Lang, NL = Niall Lusby, TT = Tilly Tillbrook, HM = Hannah Meinertzhagen, JG = Jim Gillespie.

Date	Surveyors	Start	End	Weather[9]
23/05/2016	SC1(RT, AK, RP), SC2(HB, LM, VA), SC3 (AG, MH, GL)	21:09	22:39	START: Wind F0-1 N, 0% cloud, no rain, 13˚C FINISH: Wind F1 N, 0% cloud, no rain, 10˚C
14/06/2016	SC1 (NL, RT), SC2 (LM, VA), SC3 (MH, TT)	21:31	23:01	START: Wind F1 SW, 100% cloud, dry, 11˚C FINISH: Wind F1 SW, 100% cloud, light rain, 11˚C
28/06/2016	SC1 (MH, HM), SC2 (JG, VA), SC3 (NL, RT)	21:33	23:03	START: Wind F1 W, 100% cloud, dry, 15˚C FINISH: Wind F1 W, 100% cloud, light rain, 13˚C
05/07/2016	SC1 (HM, RT), SC2 (JG, MH), SC3 (LM, NL)	21:30	23:00	START: Wind F0-1 W, 10% cloud, no rain, 15˚C FINISH: Wind F0 W, 0% cloud, no rain, 14˚C
18/07/2016	SC1 (LM, HM), SC2 (MH, RT), SC3 (GL, NL)	21:20	22:50	START: Wind F1 SE, 0% cloud, no rain, 23˚C FINISH: Wind F1 SE, 0% cloud, no rain, 21˚C
09/08/2016	SC1 (NL, LM), SC2 (MH, TT), SC3 (JG, GL)	20:45	22:15	START: Wind F2 NW, 0% cloud, no rain, 14˚C FINISH: Wind F1 NW, 0% cloud, no rain, 11˚C

[9] Wind strength is given in the Beaufort scale. This is an empirical measure that relates wind speed to observed conditions at sea or on land.

Table 8: Counts of lesser horseshoe bats from flight-line corridor surveys. S = Surveyor, D = Detector, TI = thermal imaging camera, SC = Survey Corridor.

	Surveyor count		Detector count		Camera	Total range	
Date	**S1**	**S2**	**D1**	**D2**	**TI**	**Min**	**Max**
23/05/2016							
SC1	4	8	1	1		11	11
SC2	1	4	4		No data	8	8
SC3	5	3	6	4		15	16
Total	**10**	**15**	**11**	**5**		**34**	**35**
14/06/2016							
SC1		1	1			1	1
SC2	8	2	2			10	10
SC3	10	4	5		3	16	17
Total	**18**	**7**	**8**		**3**	**28**	**28**
28/06/2016							
SC1		14			6	14	14
SC2	4	1	2			5	5
SC3	8	26	9	2	2	42	44
Total	**12**	**41**	**11**	**2**	**8**	**62**	**63**
05/07/2016							
SC1	1	3	3	1	4	8	8
SC2	1	17			4	18	18
SC3	9	11		1	1	20	21
Total	**11**	**31**	**3**	**2**	**9**	**46**	**47**
18/07/2016							
SC1	4	7	3	3	5	11	15
SC2	3	12	29	1	12	21	37
SC3	10	16	2	2		28	30
Total	**17**	**35**	**34**	**6**	**17**	**61**	**82**
09/08/2016							
SC1	2	13	1	5	3	18	20
SC2	33	8	30	27	26	60	75
SC3		10		6	3	12	13
Total	**35**	**31**	**31**	**38**	**32**	**90**	**108**
Total	**103**	**160**	**98**	**53**	**69**	**321**	**363**

7 Figures

(overleaf)

LEGEND

- Survey corridors
- Detector locations
- Surveyor locations
- Thermal imaging camera locations
- Key LHB flightlines

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PROJECT TITLE
CINDERFORD NORTHERN QUARTER,
PRE-CONSTRUCTION BAT ACTIVITY SURVEYS

DRAWING TITLE
Figure 1: Details of flightline surveys

DATE: 10.13.2016	CHECKED: MH	SCALE: 1:1,750
DRAWN: RT	APPROVED: MH	STATUS: FINAL

Sources: BSG Ecology survey data

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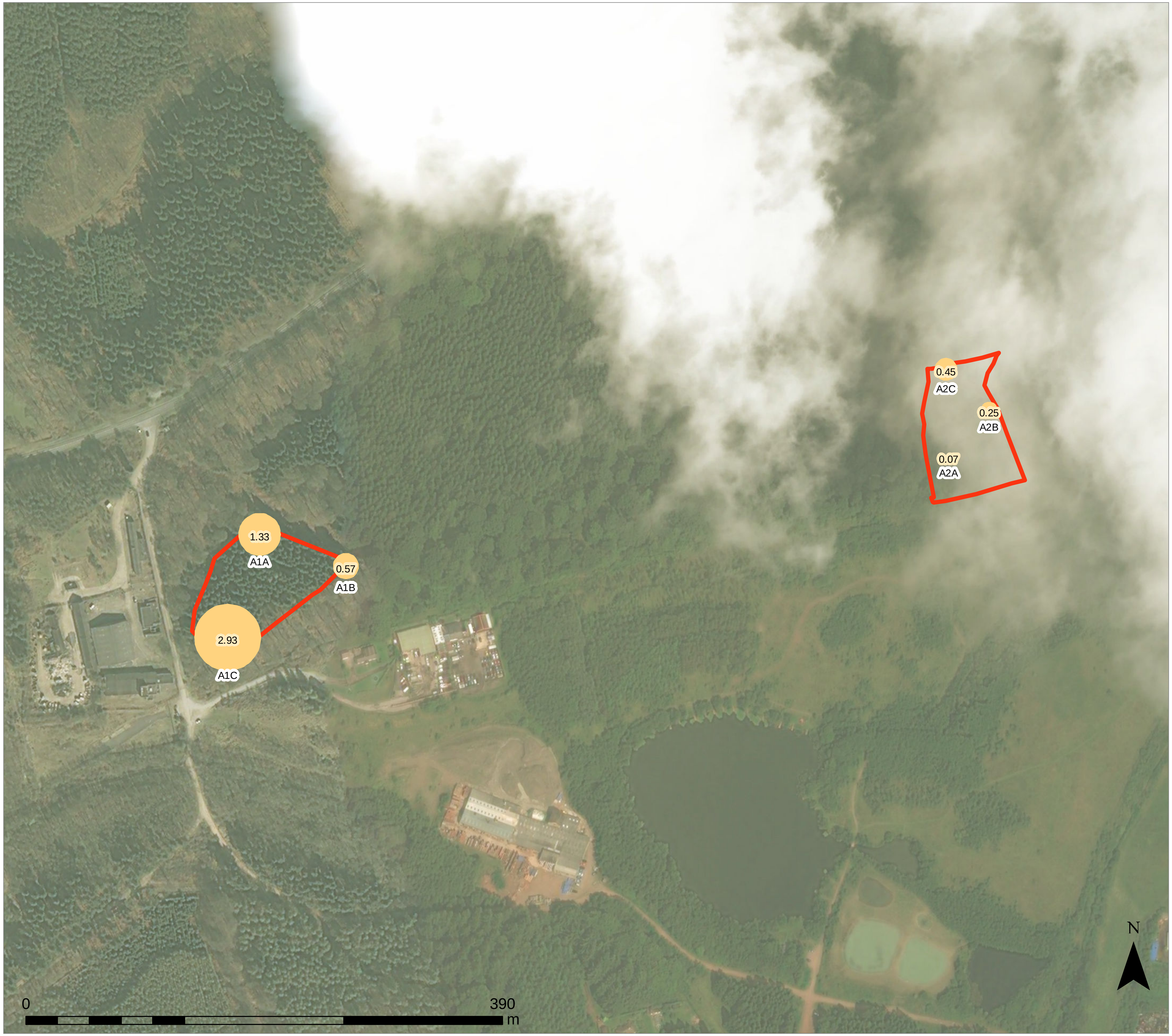

LEGEND

Automated survey areas

Lesser horseshoe bat activity (bats per hour)

- 0.1
- 0.25
- 0.5
- 0.75
- 1

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PROJECT TITLE
CINDERFORD NORTHERN QUARTER,
PRE-CONSTRUCTION BAT ACTIVITY SURVEYS

DRAWING TITLE
Figure 2: Bat detector locations and survey areas with lesser horseshoe bat activity

DATE: 10.13.2016	CHECKED: MH	SCALE: 1:3,000
DRAWN: RT	APPROVED: MH	STATUS: FINAL

Sources: BSG Ecology survey data

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8 Photographs

Photograph 1: Survey Corridor 1, from the south

Photograph 2: Survey Corridor 2, from the east

Photograph 3: Survey Corridor 3, from the west

Photograph 4: Automated location A1A

Photograph 5: Automated location A1B

Photograph 6: Automated location A1C

Photograph 7: Automated location A2A

Photograph 8: Automated location A2B

Photograph 9: Automated location A2C