# A New Methodology For Surveying Bats In Narrow Habitat Corridors

Authors: Neil E Middleton*, Christopher Gould, Craig R Macadam, Shoana Mackenzie and Kirsty Morrison

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*Correspondence details: 25 Killin Drive, Polmont, Falkirk, Scotland, UK, FK2 0QQ
email: middleneil@msn.com

## Abstract
Understanding how bats use habitats and how they are affected by changes to their surroundings is important when considering effective management techniques. The BATS & The Millennium Link (BaTML) project has designed and delivered a new survey model to monitor bats in narrow habitat corridors. This system uses heterodyne bat detectors in conjunction with a four-track recorder to survey bats as they travel through a pre-selected transect. The manner in which the model is set up can allow many factors to be studied simultaneously, including direction of flight, minimum number of bats present and overall activity. The system has been used in Scotland to study *Myotis daubentonii* (Daubenton's bat) as they commute and forage along canal corridors. It has also been adapted for use in other scenarios.

Key words: heterodyne, canals, echolocation, *Myotis, daubentonii*, Daubenton's, bat, BaTML

## Introduction

In some parts of the modern world, narrow natural/semi-natural corridors are often the only means by which some populations of fauna and flora can associate with each other and stand any chance of success in the long term. One such corridor occurs along the canal network connecting many habitats across the Central Belt of Scotland.

It was decided that a bespoke survey system and methodology to study bats in this type of environment would be beneficial. The system developed, called a Recordable Remote Heterodyne Detector System (RRHDS), has proven itself to be ideal for recording bats as they commute and forage along narrow corridors. The system can also be used in other situations when wishing to establish simultaneous activity at different points of interest.

## Methodology

The RRHDS survey model was developed to record many aspects of bat activity, including the initial direction of flight. If it is possible to establish the initial direction of flight along a narrow corridor early after sunset, experience would suggest that the bat in question is flying away from its roost and therefore the roost lies in the direction opposite to its flight (Limpens, 1993). This directional data not only provides a clue to where a potential roost may be located, but our survey model can also be repeated many times across a large area of habitat to estimate the number of potential roosts there may be in that given area.

The system can also help establish a minimum number of bats present as they commute through a narrow transect. For example, if one bat flies through travelling east to west and is quickly followed by another bat travelling the same direction, it is likely that two bats have passed through, and so on. Finally, data relating to speed of travel, bat passes and feeding buzzes can also be collected and measured.

Four heterodyne bat detectors (Batbox Ltd, Bat Box III) are each mounted onto their own separate tripod. The tripods are extended to one metre in height. Prior to being placed into their final position along the transect, each heterodyne detector (HD) is tuned to the appropriate frequency setting for the species of bat being studied.

A simple plan of the system adopted is shown in Figure1. The HDs are then connected by cabling (Digital Audio Installation Cable, Van Damme, supplied by Maplin Electronics, UK, product reference PE04E) to a four-track tape recorder (Fostex Corporation, model X24). Each roll of cabling, of which there are four, measures 100 m and is connected at one end to the headphone socket of the HD, thus disabling its speaker. At the other end the cable is connected to a channel of the four-track recorder (FTR). This process is repeated for each HD.

Figure 1: Simple Plan of the Recordable Remote Heterodyne Detector System (RRHDS) in a narrow habitat corridor

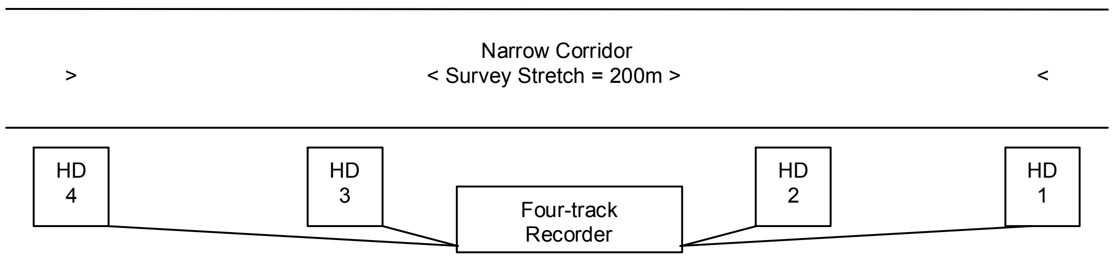
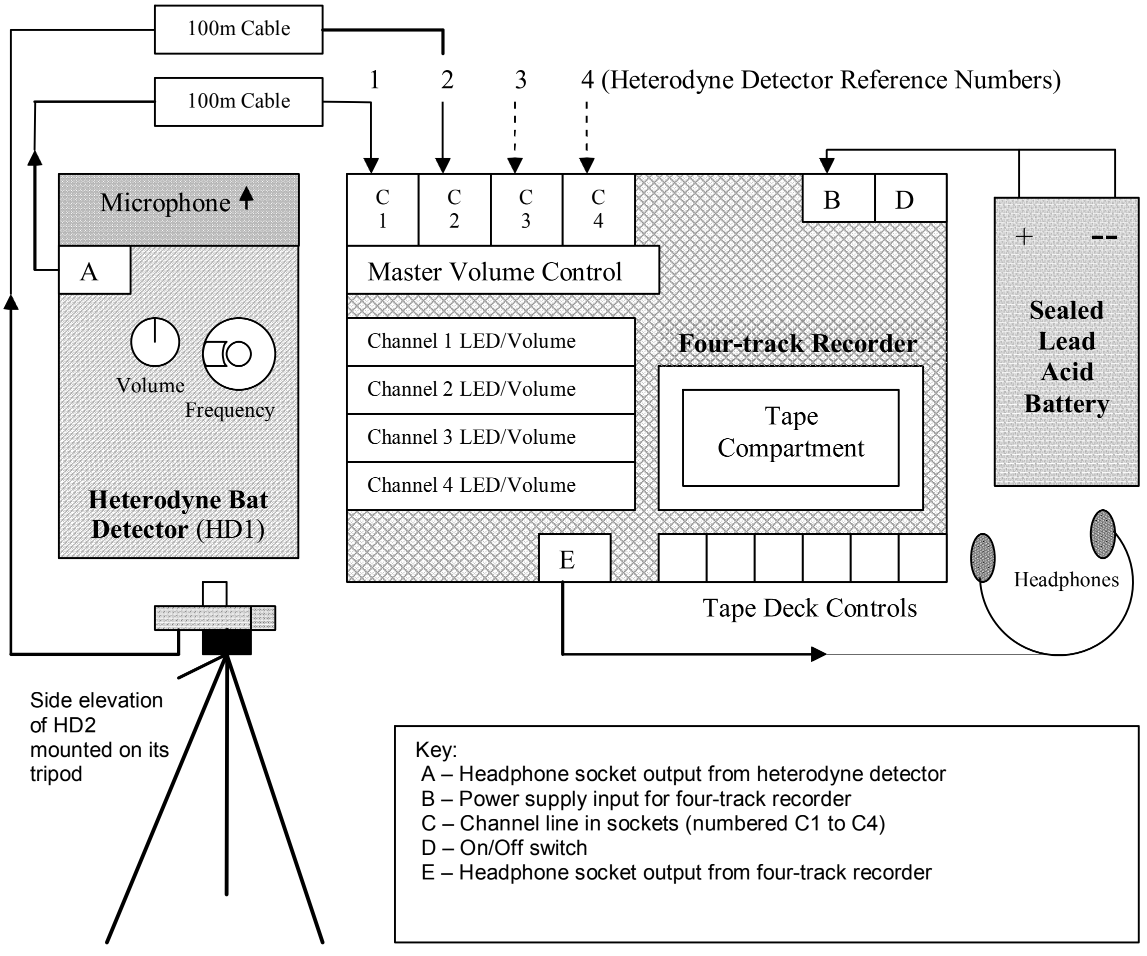



Figure 2: The Recordable Remote Heterodyne Detector System (RRHDS). Set up flow chart (items not to scale)




With 100 m of cable available it is possible to position each of the HDs up to 100 m from the FTR. This means that the model is capable of covering a 200 m transect, with the FTR in the centre. For example, two HDs are positioned 100 m away in opposite directions, whilst the other two are sited as required along the corridor between each of the first two HDs and the FTR (refer Figure 1).

The FTR model used was manufactured to work directly from a mains electricity supply. It was therefore necessary to modify it so it could be powered in the field by a sealed lead acid battery (Yuasa 7Ah/12Volt). With our set up the battery pack can supply power for well in excess of 4 hours and the option remains to power the FTR through mains electricity when required to do so during analysis. Figure 2, shows a flow chart of a typical assembly for the RRHDS model.

The FTR model used has four channels, each of which has its own LED display. This means that as a bat travels past a HD, the FTR not only tapes the bat pass to the corresponding channel providing an audio reference, but simultaneously the channel indicator gives a visual reference. This feature allows us to effectively track individual bats as they pass through the transect.

Each HD is given its own reference number corresponding with the FTR channel it is linked to. The input volume settings for the FTR are all set to 80% so as not to distort recordings. Headphones are connected to the FTR making it possible to listen for activity throughout the survey. At the appropriate time relative to sunset the survey begins and all bat activity audible to the HDs is recorded.

## Case study

The BaTML project has successfully used the RRHDS to study *Myotis daubentonii* along canal corridors in Scotland between 2001and 2005. Over this period 117 surveys were completed using this method.

**Overview**

The BATS & The Millennium Link (BaTML) project was launched in 2000 to study the bat populations along and adjacent to the canal network in the Central Belt of Scotland (Middleton *et al*, 2004a). The canal network stretches for 110 km from Glasgow (Forth & Clyde Canal) in the west to Edinburgh (Union Canal) in the east. Maps from the canal operator (British Waterways) were used to select 22 sites for monitoring surveys. These sites were located, on average, at 5 km intervals to ensure a representative coverage of the network. Each site was visited during daylight hours in 2001 to gather initial benchmark information on habitat.

As previously discussed, the RRHDS was designed with narrow commuting corridors in mind. When associated with canal habitat in the United Kingdom (UK), *Myotis daubentonii* (Daubenton's bat) was an obvious target species. These bats forage typically, albeit not exclusively, over water (Altringham, 2003; Vaughan *et al*., 1997). In particular they like to forage over smooth water emitting their echolocation parallel to the surface (Rydell *et al*., 1999; Siemers *et al*., 2001). Their technique of flying very close to the water surface, hovercraft style, is regarded by bat researchers in the UK to be diagnostic. This behaviour can often be verified visually, with as little disturbance as possible, using a red filtered light (Monhemius, 2002) as a bat 'skims' by in front of the observer.

*Myotis daubentonii* produces echolocation calls consisting of broadband frequency modulated sweeps without any constant frequency tail (Russ, 1999). The range of frequencies covered by any one call varies, however calls sweeping from as high as 88 kHz through to 36 kHz would not be deemed unusual (Parsons & Jones, 2000). Due to there being no constant frequency component to these calls, establishing a frequency of maximum energy using a HD is difficult, however *M. daubentonii* can be best listened to on a HD at frequencies between 35 kHz and 50 kHz. Whilst commuting, these pulses are generated typically at a rate of 12 to 15 per second (Stebbings, 1993) producing a rapid and regular series of 'ticks' on a HD.

In view of the species we were studying, the potential occurrence of another species of *Myotis* bat needed to be considered in our interpretations. *Myotis nattereri* (Natterer's bat) has been recorded in many parts of Scotland, although it is not commonly encountered (Haddow & Herman, 2000). Its foraging preference is thought to be more associated with woodland (Altringham, 2003). *M. nattereri* has a very similar echolocation call to *M. daubentonii* and it is possible that some of the bats we record which are not verified visually could be *M. nattereri*. We do not believe that this influences our results greatly. The visual verification of behaviour almost always (86%, N=476, BaTML, unpublished) confirms *M. daubentonii.* This is backed up by very few *M. nattereri* roosts having being found in Central Scotland. Furthermore, the incidence of this less common species being caught during our harp trapping activities close to the canal network is only 1.9% (8 out of 425 captures, BaTML, unpublished).

Each survey commenced at 30 min after sunset and recorded activity for approximately 90 minutes thereafter. All data was timed and recorded onto the four appropriately numbered tapes, which were inserted into the recorder as the survey progressed. Adopting the RRHDS methods as described, the two outer most HD detectors (HD1 and HD4) were positioned 100 m either side of the mid point, whilst the inner HD detectors (HD2 and HD3) were positioned 35 m either side of the mid point (refer Figure 1). At these distances we could be certain that a bat flying through the transect, parallel to the canal bank, would not set off more than one HD at a time. The mid point was reserved for the FTR and other support/survey equipment.

The HDs were tuned to 40kHz, thus taking advantage of a frequency where echolocating *M.*

*daubentonii* could be picked up strongly, but ultrasound from other bat species that may be present (i.e. *Pipistrellus pygmaeus*) would not dominate the recordings. The volume control on each HD was set to 50% to ensure that a strong enough signal was generated and sent to the FTR. Each HD was positioned so its microphone faced directly over and parallel to the canal water surface, and perpendicular to the canal bank. In this position bats commuting or foraging directly over the canal water surface were picked up more readily by the HDs.

**Specific data relating to one BaTML survey site**

In order to demonstrate the RRHDS fully we provide the results obtained from one of the sites which contribute towards the BaTML project. The site in question is at Tintock, north east of Glasgow on the Forth & Clyde Canal (OS Grid Ref NS685748). The data shown relates to a survey carried out on 27.07.04, one of four surveys carried out at this site during the period 2001/2005.

A habitat survey was undertaken in 2001 noting various details regarding the study site. On the evening of 27.07.04 a RRHDS survey for this site commenced at 22.06 hours (30 min after sunset).

A few days later the data from the survey was analysed as follows. The tapes were already numbered according to the order in which they were used during the survey evening. A stopwatch was used to establish the time of each occurrence on a tape. As the start time of the survey was known to be sunset plus 30 min, any activity on the tapes could be related to sunset. Headphones were used to listen for activity, with FTR channels 1 and 2 being panned to the right earpiece and channels 3 and 4 to the left earpiece. This allowed for easier interpretation of the direction sounds were coming from. All data was recorded onto paper survey forms (Middleton, 2004) and then later stored on computer database software (MS Access 2003). Commencing with Tape 1 we listened for activity relating to *M. daubentonii*. During this initial tape (see Table 1) we registered our first *M. daubentonii* bat after nine minutes as it briefly entered the transect at HD4 before turning back along the canal in the direction from which it came. One minute later a bat (possibly the same individual) entered the transect and this time flew beyond HD2 before it turned around and headed back along the canal. This bat was verified at the time of the survey to be a *M. daubentonii* as its diagnostic behaviour was witnessed using a red filtered torch.

A similar pattern of activity occurred at 43 min and then 46 min after sunset, however during the latter bat pass, two feeding buzzes were also recorded as the bat passed through HD3. At this point in the analysis it was possible to build a picture of what could be happening. It was feasible that we had at least one foraging bat entering the transect heading west, and therefore the likely location of its roost was to the east. In addition, because we had so far, four entries into the transect, we could now begin to measure activity in the form of bat passes and transect entries. As such, we were already beginning to establish directional data, a minimum numbers conclusion, as well as bat passes and feeding activity, all of which at a time relative to sunset.

As Tape 1 continued the picture became clearer still. At 48 min after sunset a bat entered the transect from the same direction as before and flew straight past the four detectors, setting each one off in sequence. Although this did not affect our minimum numbers data, it did add another bat to the overall activity measures and provided us with the confidence that if another bat approached from the east it would almost undoubtedly be a different individual.

Bat number one had only just departed the transect at HD1 when another bat entered the system from the east, again setting off all four HDs in sequence. We now had a minimum of two bats and six transect entries. One minute later yet another bat entered from the east, setting off HD4 a few times as it patrolled back and forth, before finally making its way through the transect at sunset plus 53 minutes, when two more feeding buzzes were recorded.

Adopting this system of analysis throughout, the complete set of results for Tape 1 is shown in Table 1. After analysing all four tapes the total figures were calculated and summarised. These results are shown in Table 2.

In order to undertake the analysis as described above, the researcher needs to be competent at identifying the bat species being targeted, and also able to differentiate the target species from other potential bats that could enter the survey transect. A consistent approach to the analysis is also required. After piloting the equipment against our target species early in 2001 we began to understand what the typical behaviour for *M. daubentonii* would be within the habitat and survey stretches being covered. The ability to listen to the tapes many times over, allowed us to build upon our expertise and we very quickly began to understand the characteristics to listen out for when determining what bats were doing as they flew through the transect. One such behavioural aspect surrounds how quickly it takes a bat, commuting through the 200 m transect, to get from HD1 to HD4. We have established that this would typically

Table 1: Data Collected From Tape 1, Tintock (27.07.04)

| **Time after Sunset** | **HD4**<br><br>**East(Outer)** | **HD 3**<br><br>**East (Inner)** | **HD 2**<br><br>**West (Inner)** | **HD 1**<br><br>**West (Outer)** | **Running Total Of Bats** | |
|---|---|---|---|---|---|---|
| | | | | | **Min** | **Transect entries** |
| 39 min | >< | | | | 1 | 1 |
| 40 min | ><br>< | ><br>< | >< | | 1 | 2 |
| 43 min | ><br>< | | | | 1 | 3 |
| 46 min | ><br>< | >< 2FB | | | 1 | 4 |
| 48 min | > | > | > | > | 1 | 5 |
| 49 min | > | > | > | > | 2 | 6 |
| 50 min | ><br>< | >< | | | 3 | 7 |
| 51 min | >< | | | | 3 | 8 |
| 52 min | >< | | | | 3 | 9 |
| 53 min | > | > 2FB<br><<br>> | <br><br>> | <br><br>> | 3 | 10 |

Key: > Bat travelling west
< Bat travelling east
>< Bat changing direction from heading west to heading east without a break in recording
FB Feeding Buzz (preceded by number recorded during sequence)

Table 2: Summary of results for all tapes analysed from Tintock (27.07.04)

| **Tape No** | **Bat Passes** | **Feeding Buzzes** | **First Bat Heading West** | **Probable Minimum Number of Bats** (running total) | **Transect Entries** (running total) |
|---|---|---|---|---|---|
| 1 | 30 | 4 | SS+39mins | 3 | 10 |
| 2 | 78 | 13 | | 8 | 30 |
| 3 | 39 | 14 | | 8 | 42 |
| 4 | 26 | 10 | | 8 | 49 |
| **Results** | **173** | **41** | **Roost East** | **8** | **49** |

take between 28 and 32 seconds, provided the bat was not foraging. We have since calculated the speed of travel for many of the bats we have encountered and velocities in the region of 22.5 km/h are fairly regular. This information has proven very useful in determining where we anticipate bats to be as they travel through the transect. On average, as a bat travels through the system we expect to hear sound bursts of three seconds from each HD, with roughly a six second gap between each burst.

As the bat passes one of the inner HDs we expect to see it directly in front of the mid point some 3 seconds later, at which point it can be verified using red torch light. When we hear/see a change to this behaviour we carefully consider what alternatives may be occurring. For example, one long burst of sound at two HDs, followed by two normal 3 second bursts in quick succession at the other two HDs, may suggest two bats flying through together.

## Discussion

The RRHDS has consistently delivered the results we would have hoped for and in addition has proven to be physically robust. Through using the RRHDS we have been able to establish direction of flight together with an accurate reflection of the likely minimum number of bats present. Data collected from all sites surveyed on several occasions has allowed us to build a good picture of how bats are using their habitat. We are therefore in a prime position to monitor the impact (if any) of changes to the habitat upon bat abundance and activity. The directional information has allowed us not only to estimate how many different roosts and populations of bats may exist along the total length of the corridor, but it has also allowed us to find the location of two important roosts. All of our data is timed, which allows a sequence of events relative to sunset to be produced.

The use of tripods means that surveyors are not required to stand motionless holding bat detectors in place for long periods of time. Recording the survey means that there is no risk to data being corrupt due to differing levels of experience amongst surveyors standing at different points and simultaneously noting activity. The potential for incorrect time sequences being noted by individual surveyors is also removed. Also the time it would take to dovetail and interpret results collected in this manner is removed.

We used analogue tape technology which in many respects is now regarded as dated. There would be no reason why a modern digital multi-track recorder could not be used instead, as all that is required for the model to be successful is a way of recording the data from each HD independently to its own channel for analysis at a later date. A visual channel indicator would be essential to aid interpretation. Consideration of how to adapt an alternative recorder to be powered by a battery in the field should be established prior to purchase.

As with all survey models, the RRHDS model is not without its limitations. With any survey methodology it is important when interpreting the results to consider potential pitfalls and weaknesses. If the transect gets busy with lots of bats present at any one time it can become difficult to establish directional information. This, however, becomes less important as the evening progresses as it is the data from the first few bats that give the strongest indication of roost direction. Along with directional data, minimum numbers become harder to assess as more bats pass through the system travelling in opposing directions. Even when these pitfalls exist, however, the value of collecting overall transect entries, bat passes and feeding activity is still reliable.

It is possible, depending upon the species selected and the terrain being monitored, that bats could fly behind the HDs and not set them off. This could potentially impact upon the directional data and the minimum numbers. Therefore in some situations these measures may not be as accurate as we have found with *M. daubentonii* on canals, however adapting the system to be used in some other scenarios, as described below, could still make the use of the RRHDS appropriate.

Although we originally preset our HDs to 40 kHz in order to remove interference from *Pipistrellus* spp., it would be straightforward to set the RRHDS up using a different set or combination of frequencies, thus focussing on other species. As well as in connection with BaTML, we have also used the equipment to establish bat activity in a number of other scenarios as follows:

- Whilst trying to establish bat activity in adjacent mine shafts (Middleton *et al*., 2004b), we positioned a HD at each mine entrance thus establishing which were being used by bats. During this work we were also able to split the recorded activity between *Myotis* spp. and *Pipistrellus* spp.
- A bridge was due to be worked upon by contractors and a survey was required to eliminate the possible use by bats. As well as all the normal visual checks it was decided to use the RRHDS model to position detectors either side of the structure using two frequency settings at each side. This not only eliminated the structure as holding a roost but also showed bats entering the area from outwith the immediate structure, flying under the bridge and onwards elsewhere.
- As a training tool it has proven itself to be ideal in allowing people to directly compare what individual bats sound like when detectors are set to different frequencies, i.e. setting two detectors to 45kHz and the other two at 55kHz allowed us to assist training people to understand how to differentiate the *Pipistrellus pipistrellus* from *Pipistrellus pygmaeus* in the field using HDs.
- Other potential uses considered include; river corridors, steep valleys and different positions within or surrounding large buildings.

The authors welcome any correspondence relating to this work whereby more detail is required or advice is sought for other potential uses of a similar model. To find out more about the BATS & The Millennium Link (BaTML) project please visit our website: www.batml.org.uk

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