Cyfoeth Naturiol Cymru
Natural Resources Wales

Bats and linear infrastructure

A summary of DEFRA research project WC1060 by Dr Anna Berthinussen and Professor John Altringham

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Introduction to this summary

This summary of DEFRA research project WC1060 has been produced by the report's authors; Dr Anna Berthinussen and Professor John Altringham, at the request of the project's multi-agency steering group which included representatives from DEFRA, Natural England, Welsh Government, Highways England, the Animal and Plant Health Agency, and Natural Resources Wales.

It is hoped that the standardised survey methods described can be used by nature conservation organisations, infrastructure planners and engineers, and ecological consultants to compare all phases of construction data and provide a framework for considering mitigation methods. The summary provides a brief examination of current evidence, protocols for survey, and suggested mitigation measures.

This report is published and hosted by Natural Resources Wales at the request of the steering group.

The full WC1060 report and appendices can be found at http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=18518
Alternatively it can be obtained from Anna and John at www.conservationfirst.co.uk

Background: why was research project WC1060 necessary?

Recent research has shown that roads can have negative impacts on bats with landscape scale reductions in bat activity and diversity (Berthinussen & Altringham 2012a, 2015), reduced reproductive success (Kerth & Melber 2009), and mortality through collisions with traffic (Lesinski 2007, Lesinski et al. 2010, Russell et al. 2009). As all UK bat species are protected by law, they must be considered in the Environmental Impact Assessment (EIA) of developments such as roads, and any unavoidable adverse impacts must be mitigated.

Environmental Statements should be prepared in an objective and systematic way and provide sufficient information for effective decision-making and to inform the mitigation process. They should also provide baseline activity data which can be compared against data collected post-construction to draw conclusions about the effect of the development and the effectiveness of mitigation. However, there has been a lack of consistency in the ways that data are collected, analysed and interpreted and in practice the variable quality and quantity of data have frequently made it difficult to draw reliable conclusions.

Recent reviews of case studies of bat mitigation in the UK found that most reports were qualitative and inconclusive (Altringham 2008, O'Connor et al. 2011, Berthinussen & Altringham 2012a, b, 2015), and failed to make the important distinction between the use of structures by individual bats and the effectiveness of structures in maintaining local population sizes. Without this information it is impossible to know whether mitigation measures are effectively protecting local bat populations from adverse effects, as required by law. Reliable methods are needed to ensure a more efficient development process and more positive outcomes for bats.

Defra research project WC1060 (Berthinussen & Altringham 2015) developed standardised cost-effective survey methods to assess the effect of linear transport infrastructure on bats (on a landscape scale) and the effectiveness of mitigation measures such as crossing structures (on a local scale). The focus was on road construction but rail was also considered. The methods are quantitative, replicable and statistically robust. They can be used for the comparison of pre, during and post-construction data, and are suitable for providing baseline data for Environmental Statements. Clear protocols have been created for use by conservation practitioners and the consultancy industry. The effectiveness of some currently used mitigation measures were assessed while testing the methods, and recommendations are made to inform best practice.

Summary of WC1060 survey methods

The protocols reflect a compromise between providing robust data from which to draw reliable conclusions and the need for cost-effectiveness. They specify the minimum number of surveys that should be conducted per site to provide sufficient data for analysis – it may be necessary to conduct more work if the results are inconclusive or rare species are the focus of the work.

Two survey protocols address the two different aspects specified in the aims:

1. A landscape scale survey method using transects to assess the effect of linear infrastructure on bats at a population level
2. A local scale survey method to assess the effectiveness of mitigation measures such as crossing structures over or under linear infrastructure

These methods should be used in conjunction with existing practices: desk studies and fieldwork to identify known roosts, foraging areas and commuting routes, particularly of rare and vulnerable species. The identification of points where bats cross the proposed road is vitally important, since it is in these areas that mitigation efforts must be concentrated. Some vulnerable species are difficult to identify acoustically. If their presence is detected by other methods, the precautionary principle should be adopted and either the assumption made that they may be using all crossing points in the survey area, or that further survey work is necessary.

The landscape scale transect protocol measures bat activity and species diversity over a large area surrounding the linear infrastructure, and uses statistical modelling to detect changes in activity and diversity related to its presence. A reduction in bat activity and/or diversity in proximity to the infrastructure indicates the strong likelihood of a negative impact on nearby bat populations. Pre-construction surveys provide baseline data for comparison with during and post-construction data, to detect change. The permitting authorities are required to assess the impact of a scheme on the favourable conservation status of bat populations affected and it may be necessary to undertake large-scale pre-construction surveys to provide information on the status of bat species in the area. Landscape scale post-construction monitoring may be needed to assess the effects.

The local scale protocols provide a simple method for objective assessment of mitigation structures. Set definitions and criteria are used, and the effectiveness of crossing structures is assessed by comparing the number of bats using the structure to cross, with those using the original pre-construction commuting route, and those crossing at risk of being killed by traffic.

In developing a monitoring plan, whatever the methods and protocols used, the plan must be designed to address focused, relevant and quantitative objectives. The first step in developing a plan should be to ask: what *specifically* are we trying to learn? These questions should be set down explicitly at the beginning.

What were the key findings of WC1060 and earlier studies?

Motorways (established, pre- and during construction) had a consistent negative effect on bat abundance and diversity. The effects of A roads were inconsistent, with effects noted on two of the three single carriageways studied but not on the one dual carriageway, and further research is needed to explain these differences. These findings corroborate those of Berthinussen & Altringham (2012a). One of the two railway sites studied also had a negative effect on bat activity and diversity.

- The effectiveness of nine existing mitigation features for bats on roads was assessed: three underpasses, three wire bridges, an overpass, an environmental bridge and a green bridge.
- One underpass and the green bridge were effective in guiding a large majority of bats under or over the roads.
- Underpasses were more likely to be used successfully by commuting bats than overpasses and bat gantries/wire bridges, both of which were consistently ineffective.
- A bat gantry erected close to a known commuting route was not being used by bats nine years after construction (Berthinussen & Altringham 2012b).
- Green bridges appear to have considerable potential as mitigation structures.
- The results suggest that the effectiveness of crossing structures increases with their size, connectivity and similarity to natural linear features.

Outputs from WC1060

- The results from all sites tested are presented and discussed
- Full survey protocols, with technical advice on data format, organisation and storage, and full instructions for data analysis
- Example datasheets and spreadsheets with step-by-step instructions and coding for the recommended software
- Recommended criteria for drawing conclusions about the effects of linear infrastructure and the effectiveness of mitigation measures
- Recommendations for improving on current mitigation techniques

What follows is a brief summary of the protocols, with guidance on when and where the protocols should be used (including considerations of scale), their limitations and special considerations for particular species or situations. Recommendations are also given, highlighting the most promising approaches and those shown to be ineffective or that have yet to be effectively tested.

Recommendations from WC1060 for surveying bats along linear transport infrastructure

The methods will provide comparable pre and post-construction data and baseline activity for the Environmental Statements that are used to assess the potential impacts of a development. They should be conducted in addition to other pre-construction surveys (using acoustic, radiotracking and other methods) that are used in the early stages of road planning to identify bat roosts and important foraging habitats that may be destroyed or disturbed by the scheme.

Use a combination of landscape scale surveys to measure spatial changes in bat activity and diversity in relation to the road/railway *and* local scale surveys of specific bat flight paths to assess the effectiveness of mitigation features designed to guide bats safely under or over roads/railways. Key points for each are given below. Detailed instructions for survey and analysis are given in **Appendices E and G of WC1060**.

Appropriate scale of survey

The scale of survey and monitoring should be appropriate to the likely impact of the development, taking into account the habitat through which it will pass and whether it is a new off-line scheme or an on-line upgrade. A motorway, heavily-used dual-carriageway or a mainline railway, passing through species-rich primary habitat, will require comprehensive survey and monitoring. Upgrade of a dual-carriageway through an urban or industrial area will require much less, with detailed attention given primarily to green corridors.

Landscape scale effects

This method should be used for major schemes. In order to maximise the use of the data, the transect protocol can be used as part of a preliminary ecological assessment or initial survey to identify areas where further or more detailed work may be required. The method will not usually be either appropriate or practical for minor roads or short sections of road. On short sections it will not be possible to survey the minimum 10 transects and on minor roads the effort would be disproportionate to the likely effects.

Full spectrum direct-sampling detectors are recommended to maximise sound recording quality, and for the most reliable species identification. Automated identification software may be used, but accuracy should be checked.

Conduct the transect survey protocol (**Appendix E of WC1060**) prior to construction to provide baseline data. This should be done over at least two seasons where possible.

Repeat during construction and for a minimum of three years post-construction. Frequency of survey will depend upon the project goals but the effects of linear infrastructure on bats may persist for many years, and long term monitoring is important.

A minimum of ten transects of 1 km length (with 10 min spot checks at 100 m intervals – i.e. 100 m steps perpendicular to the development) should be completed per site, at the same time each year (ideally June-August). Surveys should start 30 min after sunset and only be done in ‘good’ weather: temperature >7°C, wind <20 km/h (~12 mph), no rain. Where possible, an equal number of transects should be selected on each side of the road or railway and equal numbers walked towards and away from the road or railway.

Transects can be located along minor roads, bridleways or public footpaths. Habitat variation must be taken into account as described in **Appendix E of WC1060**. More transects may be needed if specific bat species are of interest, particularly those that are less common. Ideally, transects should be at least 500 m apart. Progressive shortening of this distance increases the possibility of pseudo-replication, but distances down to 200 m are acceptable. Distances between transects will depend on the scale of the development. For example, every 200-400 m on a 3 km bypass, several km on a much longer road. Very long developments may need to be considered as a series of smaller projects.

An alternative to walked transects would be the placement of automated, stationary loggers at the same measurement points along the 1 km transects. This would require a greater outlay in equipment, but would allow data to be gathered simultaneously over longer time periods. Analysis methods would be the same.

Nyctalus and *Eptesicus* species should be excluded from the data for the following analyses of total bat activity, as neutral or positive impacts on these species may affect the results.

Compare pre-construction data with during and/or post-construction data using appropriate statistical tests (such as t-tests or one way anova) to look for changes in bat activity over time. If bat activity (either total and/or for individual species) has significantly declined, the infrastructure has had a negative effect since construction.

Analyse post-construction data using the GEE modelling method to look for changes in total bat activity in proximity to the infrastructure, and repeat the analyses for all species with sufficient data. The analysis may also be repeated for bat diversity.

If the effect of distance from the infrastructure is positive (with a significance level of $P < 0.05$) or bat activity (either total and/or for individual species) is predicted to increase by at least 20% (regardless of statistical significance) between 0 and 1 km from the infrastructure, the effect is considered to be detrimental to local bat populations. Rare or vulnerable populations may need special consideration.

Results of statistical tests and models should be presented in reports in text and table format, and data should be displayed visually using boxplots.

Local scale & mitigation

Full spectrum direct-sampling detectors are recommended to maximise sound recording quality, and for the most reliable species identification. Automated identification software may be used, but accuracy should be checked. For visualising bats, night vision scopes/cameras and thermal cameras of sufficient resolution should be used. On narrow schemes, natural dusk and dawn lighting may be sufficient in some cases.

Identify bat commuting routes that will be severed by the scheme prior to construction (as detailed in **Appendix G of WC1060**) to inform the placement of mitigation structures.

Before construction, complete a minimum of six 60 min dusk or dawn surveys at each location where mitigation is to be installed (following the local scale survey protocol in **Appendix G of WC1060**). Surveys should be 60 min duration, commencing either at sunset or one hour before sunrise.

Surveyors should familiarise themselves with each site and be able to confidently judge heights and distances to 1 m intervals within the survey area. This can be done by erecting vertical and horizontal LED marker poles or measuring and locating reference points in the survey area. The aim of the survey is to track the route of each bat that crosses the road, in particular its height above the ground and, in during and post-construction surveys, its position in relation to any mitigation crossing structures.

The information to be recorded for each bat is:

- ***A record number*** for each observation made
- ***The precise (ideally to the second) time of the observation***
- ***A call/track identifier*** to allow the observation to be paired with the relevant sound file
- ***The height of the bat above the road to the nearest metre***
- ***The distance of the bat from the feature to the nearest metre.*** This will be the horizontal distance from the mitigation structure, where one is in place. Prior to construction this may be the distance from the commuting feature such as a hedgerow or treeline.
- ***The side of the feature that the bat crossed on.*** Use compass bearings
- ***The direction the bat crossed.*** Use compass bearings
- ***Weather variables and other comments***

More surveys, running later into the night, may be necessary if vulnerable, woodland-adapted species are involved, such as Bechstein's or horseshoe bats.

Repeat the local scale survey protocol at each location where mitigation is installed at the same time each year during construction and post-construction. Survey for a minimum of three years post-construction (frequency of survey will depend upon the project goals but the effects of linear infrastructure on bats may persist for many years, and long term monitoring is important).

For schemes that have already been completed, surveys may be carried out post-construction to provide a basic assessment of the mitigation. However in the absence of pre-construction data this will not give a complete picture of effectiveness or the impact of the scheme and is insufficient for future schemes.

Compare the total number of bats crossing at each site before, during and after construction, and the number of bats considered to be using the mitigation structure in question (according to set definition of 'use'), and the number crossing the scheme at risk of collision with traffic.

Mitigation structures are considered effective when the number of bats using the commuting route has not declined substantially (by a statistically significant decline of 10% or more) since construction, *and* at least 90% of crossing bats are using the structure to cross safely. Special consideration will need to be given to rare and vulnerable populations. Not all species may be affected in the same way.

Results should be presented in reports in text and table format, and data should be displayed visually using boxplots. An optional kernel density estimation plot may also be produced to show the position and density of crossing bats at a site.

The results from both methods above should be considered, to give an overall picture of the impact of the infrastructure scheme on a landscape and local scale, and the effectiveness of any mitigation structures over the scheme.

The aim is for linear transport infrastructure schemes not to have a detrimental impact on local bat populations, and for effective mitigation of any negative impacts. This means that bat abundance in the landscape surrounding the scheme should not drop significantly during or after construction, the number of bats using a commuting route should not decline substantially during or post-construction, and at least 90% of bats crossing the scheme should do so safely without risk of traffic collision. It is also important to look at individual species, particularly those at risk due to rarity, ecology or proximity to the development. This may require some modification or extension of the minimum survey protocols recommended.

Recommendations for bat mitigation along linear transport infrastructure

Further research is needed to make detailed recommendations, especially on structure design. Based on currently available evidence the best way to maintain safe bat commuting routes and increase the permeability of linear transport infrastructure is a combination of appropriately designed underpasses and green bridges. Wire bridges/gantries are unlikely to be effective since no design tested so far has shown any promise and they meet none of the essential ecological or behavioural needs of bats. The design and placement of mitigation structures will be site and species-specific. However, the following general recommendations are likely to contribute significantly to the success of these crossing structures:

1. <u>Mitigation should be integrated into the scheme from the earliest opportunity.</u> Mitigation should be considered during the planning and design stage of the infrastructure so that it can be incorporated effectively.

2. <u>Crossing structures should be placed on the exact location of existing bat commuting routes.</u> Attempts should not be made to divert bats from their existing commuting routes.

3. <u>Crossing structures should not require bats to alter flight height or direction.</u> This will depend on the topography of the site. If the road is to be elevated above ground level an underpass may be used to preserve the commuting route below it, or if the road is in a cutting a green bridge may be used to carry the commuting route over the road.

4. <u>Crossing structures should maintain connectivity with existing bat commuting routes.</u> Connectivity must be maintained with undisturbed bat flight paths (e.g. treelines, hedgerows, woodland rides and streams), and bat habitat (e.g. woodland) within the surrounding landscape. Crossing structures should not be exposed or sited within open ground.

5. <u>Over-the-road structures such as green bridges should be planted with vegetation.</u> Vegetation should be continuous and connected (see above) and sufficiently mature before road construction (e.g. by planting either relatively mature trees or fast growing tree species in advance of construction).

6. Underpasses should be of sufficient height. Underpasses should be as spacious as possible with height being the critical factor. The minimum requirements for underpass height will be species-specific. Required heights will generally be lower for woodland-adapted species (~3 m) compared to generalist edge-adapted species (~6 m), but larger underpasses will accommodate more species.

7. Green bridges should be of sufficient width. In addition to being vegetated, green bridges should be as wide as possible, to simulate ‘natural’ habitat as closely as possible. Further research is needed to determine exact dimensions, but a 30 m wide green bridge was found to be effective.

8. Crossing structures should be unlit. The effects of light on bats are species-specific but lighting should be avoided.

9. Access and connectivity must be maintained. It is important that access to crossing structures is maintained (e.g. grilles should not be installed on underpasses) and that connecting vegetation is retained indefinitely or for as long as the mitigation structure is required.

10. Disturbance should be minimised during installation of mitigation structures. For example, by limiting noise and light pollution along the bat flight path, minimising vegetation clearance, installing suitable temporary crossing structures (which should also be subject to monitoring and evaluation), completing the installation as quickly as possible and ideally avoiding the summer months when bats are most active.

These recommendations are based on the evidence currently available. With appropriate monitoring and assessment of future mitigation schemes the evidence base can be improved. This could come from properly conducted and shared survey and monitoring by the consultancy and construction industries as part of ongoing projects.

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