# Reviewing the evidence on mitigation strategies for bats in buildings: informing best-practice for policy makers and practitioners

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## EXECUTIVE SUMMARY


**Aims and objectives**

This study aimed to provide evidence to planners, developers and ecological practitioners on the efficacy of bat roost mitigation and compensation to help them ensure that mitigation approaches are evidence-based and beneficial for bats.

***Primary objectives***

(a) To determine the effectiveness of mitigation strategies for bats within buildings.
(b) To identify which characteristics of mitigation features are associated with the likelihood of successful retention of bat populations post-development.

***Secondary objectives***

(a) To assess the extent of bat roost mitigation and post-construction monitoring that is currently occurring.
(b) To determine what methodological improvements could be made to the collection and reporting of pre-development survey data and post-development monitoring.

**Rationale**

Despite the relatively widespread use of artificial bat roosts as both a mitigation strategy and habitat enhancement tool, relatively little research has been conducted on their effectiveness. Most research has focused on pre- and post-development case studies which, whilst valuable, are rarely generalizable. Given that the amount of data collected annually by ecological practitioners dwarfs that which could be collected by research scientists, in this project we aimed to harness this resource to assess the effectiveness of bat mitigation in buildings.

**Methods**

1) Licence reports outlining i) pre-development surveys, ii) mitigation strategies, and iii) post-development monitoring were obtained from both the Statutory Nature Conservation Bodies (SNCBs) and directly from ecological consultants.

2) Case studies involving *Myotis* spp., common pipistrelles (*Pipistrellus pipistrellus*), soprano pipistrelles (*P. pygmaeus*) and brown long-eared bats (*Plecotus auritus)* were specifically

requested, as these species are commonly encountered during developments involving buildings, and they have UK- and Ireland-wide distributions.

3) Data was extracted from the reports in a systematic manner, and ecological practitioners were contacted for additional information when required.

4) Bat roost presence and roost sizes were compared pre- and post-mitigation to determine whether bat roosts are being retained, and to assess whether the extent of disturbance (e.g. destruction versus modification) or the type of mitigation feature used could predict success.

5) Features of bat lofts, bat boxes and reroofing projects were identified that were linked with a greater probability of bat occurrence and higher population levels post-development. The probability of bat occurrence within compensatory roosts over time was also assessed.

6) During data extraction, the quality of monitoring reports was evaluated to develop recommendations to facilitate the transition to a robust and transparent monitoring process.

**Results and interpretation**

1) The probability of retaining bat roosts within a building following mitigation was strongly dependent on the nature of the structural change to the roost. If a roost was destroyed there was a lower probability of bats returning to a compensatory roost compared with a modified roost. The provision of a bat loft as mitigation was usually more effective than the use of bat boxes at providing compensation for bats. Roosts that were modified because of reroofing work were relatively successful at retaining similarly sized populations post-development, particularly for brown long-eared bats.

2) Newly created bat lofts attracted bats at just over half the number of sites, with post-construction monitoring determining that 52% of lofts contained bats. Brown long-eared bats used new bat lofts most frequently, followed by common pipistrelles and then soprano pipistrelles. The probability of pipistrelles occupying a new bat loft was strongly dependent on the number of roost entrances provided (which for pipistrelles, and other crevice-dwelling species, may also act as roosting opportunities). Similarly, there was a marginally significant relationship between the number of roost entrances and the probability of brown long-eared bats within new lofts. Although the results indicate that increasing the number of roost entrances will increase the probability of bats occurring post-development, it is likely that an upper limit will exist whereby additional entrances will create draught and light exposure to the loft.

3) Analysis of bat box data was restricted to sites where bat boxes were used as the primary mitigation or compensation measure. A relatively low proportion of sites which used bat boxes were successful at retaining bats (31%). Where bats were present in bat boxes post-

development, the overwhelming majority were identified (either visually or through the assessment of droppings) as pipistrelles. Increasing the number of bat boxes deployed across a site increased the probability of at least one of the boxes becoming occupied. There was also a marginally significant relationship between the number of bat boxes deployed and the number of bats contained within them.

4) In buildings that were modified due to reroofing works, 67% of buildings retained bats. The probability of pipistrelles returning to a modified roost was considerably greater if roost enhancements (e.g. the provision of rough sawn timber crevices) were provided alongside reroofing works. There was a marginal but significant relationship between the number of roost entrances installed and the probability of all bat species returning to the modified roost in comparable numbers to that found within pre-construction surveys.

5) The likelihood of detecting bats within compensatory roosts increased over time and with additional surveys; however, there was considerable variability between sites in the number of bats found between monitoring years. Monitoring reports were found to vary considerably with regards to the extent of key information contained within them. Critical information such as that detailing which mitigation features were observed (i.e. the % of roost entrances that were observed for bat emergence) was lacking in most cases.

**Conclusions**

Evidence-based mitigation is key to conserving bat populations efficiently and effectively. This study has demonstrated how ecological consultancy data could be used to further our understanding of the efficacy of mitigation strategies. The constraints we faced in terms of accessing and extracting data highlights the pressing need for the development of an online system, hosted by the SNCBs, which captures and securely stores mitigation data. This will generate quantitative data which is comparable between cases, will allow the SNCBs to better determine if they are achieving their statutory obligations, and will ensure that information can be shared with ecological consultants to inform effective mitigation in the future.

## Chapter 1: Context

### *1.1 Terminology*

In this report, the term ‘development’ is used to encompass a range of activities that relate to the construction, modification, restoration or conversion of buildings. In contrast to Mitchell-Jones (2004), the term does not implicitly refer to “operations that have the potential to impact *negatively* on bats and bat populations” but instead takes a neutral stance.

Mitigation refers specifically to measures that reduce and/or minimise impacts within the site boundary such as changes to timing to avoid sensitive periods or reductions to the extent of the project. Compensation refers to the measures taken to make up for the loss of, or permanent damage to, biological resources through the provision of replacement areas. Any replacement area should be similar to or, with appropriate management, have the ability to reproduce the ecological functions and conditions of those biological resources that have been lost or damaged (CIEEM 2017).

### *1.2 Overview of bat mitigation*

Despite the relatively widespread use of artificial bat roosts as both a mitigation strategy and habitat enhancement method, relatively little research has been conducted on their effectiveness. Although there are many anecdotal case studies available describing mitigation success/failure (e.g. Mitigation Case Studies Forum 2017), there have been relatively few attempts at combining case studies to produce findings that are statistically robust and that can be generalised to new situations (Table 1.1 and Table 2.2).

With the exception of cases uploaded to the Bat Conservation Trust’s “Roost” website, it is evident that mitigation success varies considerably between studies (Table 1.1)[1]. The low level of mitigation success found in other studies may reflect the relatively short time period between the implementation of a mitigation strategy and post-development monitoring. For example, in Mackintosh (2016), most replacement roosts had been in place for less than

[1] The Roost website is likely to be unrepresentative of mitigation success given that case- studies were submitted with the knowledge that they would be shared publicly.

two summers prior to monitoring and the oldest for three summers. Occupancy rates of artificial roosts can be time-dependent (Flaquer *et al*. 2006); it is therefore possible that bats may have displayed a higher degree of acceptance of the mitigation features over a longer period of time, which was not captured in the Mackintosh (2016) study.

A prevailing theme throughout the previous studies was that there was a necessity to undertake research into the predictors of mitigation success and to determine how this differs between species and for different mitigation measures (e.g. Stone *et al*. 2013). This study aims to address the uncertainty in the efficacy of mitigation and to ensure that mitigation approaches are evidence-based and beneficial for bats.

**Table 1.1. Overview of the current research that has been conducted in the UK assessing the effectiveness of bat mitigation in buildings.**

| Project | Key outcomes | Reference |
|---|---|---|
| Effect of barn conversion on bat roost sites in Hertfordshire, England | 36 barn conversions surveyed for bats following development<br>Only eight of these 36 units were being used by bats, namely Natterer's bat (*Myotis nattereri)*, brown long-eared bat (*P. auritus*), pipistrelles (*Pipistrellus* spp.) and serotine bat (*Eptesicus serotinus*)<br>13 barns had no bat use with no potential for bats to return. | Briggs (2004) |
| Snowdonia Bat Mitigation Pilot Project | 20 sites which had undergone mitigation inspected<br>Evidence of bat usage found in 75% of cases<br>7 projects (35%) were compliant with planning conditions | Waring (2011) |
| Bats and Licensing: A report on the success of maternity roost compensation measures | 28 maternity roost sites monitored<br>Compensation installed as described in plan at all sites<br>Evidence of bat usage found in 39% of cases<br>Sites which retained existing access showed least reduction in bat numbers<br>Sites which relied only on boxes showed the greatest reduction in bat numbers | Mackintosh (2016) |
| Mitigating the effect of development on bats in England with derogation licensing | Most licensees (67%) failed to submit post-development reports<br>Information provided by licensees was inadequate and inconsistent<br>Bat lofts more successful at retaining bats (74%) than bat boxes (13%) | Stone *et al*. (2013) |
| An investigation of the impact of development projects on bat populations | Bats present in 20% of bat boxes used as compensation<br>An additional 30% of boxes showed signs of previous use | Aughney (2008) |
| Unpublished local authority study | Presence of bats at 45% of post-development sites<br>Frequent cases involving incorrect installation of mitigation | N/A |
| Mitigation for bats: the National Trust experience | Inconsistencies in the type and quality of monitoring data<br>84% re-occupancy rate post-works for licensed cases<br>Natural fluctuations of some species can obscure meaningful analysis | Hodgkins & Smith (2012) |
| Roost: The Bat Roost Replacement & Enhancement Resource | 24 cases submitted by practitioners outlining successful mitigation practices | Bat Conservation Trust (2017a) |
| A Review of The Success of Bat Boxes in Houses | 9 bat roost boxes within roofs were assessed (8 designed for pipistrelles, 1 for brown long-eared bat)<br>Of the 8 boxes designed for pipistrelles, 7 were occupied by roosting bats. The box designed for the brown long-eared bat was never occupied. | Bat Conservation Trust (2006) |
| Mitigating the Impact of Bats in Historic Churches | Natterer's bat were not recorded using bat boxes that were provided for them<br>Natterer's bat frequently used 'boxed-in' areas that restricted access to main interior of building | Zeale *et al*. (2016) |
| Performance of artificial maternity bat roost structures near Bath, UK | Demolition and redevelopment of converted farm house containing brown long-eared bat and common pipistrelle bat maternity roots<br>Construction of bat house and bat wall structures built in compensation Roosting brown-long eared bats established within 18 months, with observed numbers<br>Indicating that maternity colony likely re-established.<br>Common pipistrelle maternity roost yet to re-establish after six years | Garland *et al*. (2017) |
| Mitigation Case Studies Forum | Proceedings from the Mitigation Case Studies which was conducted as a first step in addressing the lack of evidence in the efficacy of bat roost mitigation.<br>Poll highlighted that majority of attendees thought that monitoring results are not being analysed and shared, particularly if there was a failure. | Bat Conservation Trust (2017) |
| The Lesser Horseshoe Bat: Conservation Handbook | A wide range of ideas for modifying, enhancing and creating roosts for lesser horseshoe bats, with practical advice on improving and adapting buildings as roosts. | Schofield (2008) |

**Table 1.2 Selective overview of current literature assessing the occupancy of bat boxes. Additional literature can be found by consulting the literature reviews in either Rueegger (2016) or Mering & Chambers (2014).**

| Project | Key outcomes | Reference |
|---|---|---|
| The Vincent Wildlife Trust's Irish Bat Box Scheme | Bats present in 20% of bat boxes used as compensation<br>Seasonal occupancy rates; more bats present later in the season<br>Consultants expressed concern regarding lack of post-development monitoring | McAney & Hanniffy (2015) |
| Managing competition between birds and bats for roost boxes in small woodlands | 196 bat boxes inspected for occupancy between 2005 and 2009 (21 sites)<br>Occupancy does not increase above 30% utilisation with an increasing number of boxes on site after 8 boxes | Meddings *et al*. (2011) |
| A comparison of different bat box types by bat occupancy | Bat usage found in 11 - 33% of boxes; dependent on box type<br>Seasonal variation in bat occupancy rate with nesting birds outcompeting bats in spring. | Dodds & Bilston (2013) |
| An analysis of the usage of bat boxes in England, Wales and Ireland | Bat box occupancy rate varied from 15% in Devon and west Wales, to 4% in the Midlands<br>Occupancy rates, bat counts and species counts all increased with length of time the boxes were established<br>Bat box height had a significant effect on occupancy and time to first use by Natterer's bats | Poulton (2006) |
| Thinking outside the box: A review of artificial roosts for bats | Literature review of 47 publications on creation of artificial boxes<br>Few studies measured height or microclimate in context of attracting bats<br>Colonisation rates ranged from 7% to 100% | Mering & Chambers (2014) |
| Bat Boxes - A Review of Their Use and Application, Past, Present and Future | Literature review of 109 publications<br>No conclusive evidence was found that bat box installation height is important | Rueegger (2016) |

# Chapter 2: Contextualising the scale of bat mitigation and post-development monitoring

## 2.1 Introduction

Ecological consultancy work in the UK has rapidly expanded over the last two decades, to meet the requirements of the Habitats Directive, the Environmental Impact Assessment Directive, and planning policy. Stone *et al*. (2013) estimated that, from 2003 to 2005, a total of £4.13 million was spent on bat lofts and bat boxes in England as compensation, in addition to the associated consultancy fees and costs, habitat mitigation and Natural England's administration. However, there has been no review of the current scale of mitigation. In this project, the extent of mitigation and post-development monitoring currently occurring in the UK and Ireland was assessed, and the perspectives of ecological practitioners on post-development monitoring were investigated.

## 2.2 Methods

A semi-structured questionnaire was designed to assess the extent to which bat mitigation and post-development monitoring occur (Appendix 1). This was distributed in February 2017 via the CIEEM mailing list to all CIEEM members (4,986 individuals), most of whom are practising ecologists. The questionnaire was primarily designed for ecological consultants, but flexibility was incorporated via open questions that could be answered by a range of respondents including ecologists from local planning authorities (LPAs) and SNCBs. The questionnaire was hosted via online survey software (Survey Gizmo) and was active from 1st February-1st May 2017.

## 2.3 Results

There were 261 respondents to the questionnaire. These included 228 ecological consultants, 15 LPA ecologists, and 18 other respondents including representatives of the SNCBs and voluntary roost visitors. The geographical distribution of the respondents was as follows: England 80%; Scotland 8%; Wales 8%; Northern Ireland 1%; and Republic of Ireland 3%.

*The extent of bat-related projects undertaken by ecological consultants*

Sole practitioners deal with a mean of 20 (95% Confidence Interval (CI): 15 – 25) projects relating to bats in buildings annually, whereas larger consultancies containing at least two staff members handle an average of 47 (95% CI: 24 – 70) cases a year. Overall, a mean of 68% (95% CI: 64-73) require mitigation, whilst 64% (95% CI: 59 – 69) require a European Protected Species (EPS) licence, highlighting that most cases which require mitigation are undertaken under licence.

Only 11% of ecological practitioners thought that the evidence base currently exists to enable them to make an informed decision on best-practice mitigation strategies. In contrast, 70% thought the evidence base partially exists, whereas 19% thought they were unable to make informed decisions due to the lack of evidence. Bat boxes are used widely as a mitigation tool, with 76% (95% CI: 72 –80) of cases involving their deployment either in isolation or in combination with other mitigation strategies.

*The extent of, and constraints on, post-development monitoring*

Post-development monitoring is recommended in 51% (95% CI: 47 –56) of EPS licence cases. Just over a third of consultants reported that they had encountered occasions where monitoring had been recommended and the client was willing to pay, but this action was deemed unnecessary by an SNCB (29% of occasions), a Local Planning Authority (2%), or both (3%).

There was a perception amongst 34% of practitioners that this situation had become increasingly frequent during the past five years, in contrast to 28% of practitioners who did not perceive there to have been a change. The practitioners who had observed a change were asked why they thought this might be the case. Their explanations can be broadly split into four distinct categories:

*i) Broader definition of 'low impact' (33% of responses)*

Many respondents from England stated that the introduction of the Natural England Low Impact Bat Class Licence has led to a reduction in monitoring at 'low impact' roosts. Similarly, stronger adherence to the Bat Mitigation Guidelines (Mitchell-Jones 2004) was felt to have reduced the necessity of conducting monitoring at roosts of lower conservation significance. For example, comments included:

> "*Relaxation in 'policy' to monitoring of low impact/low status sites.*"

> "*Because non-maternity roosts are considered low impact*"

> "*Proportionality / stricter adherence to bat mitigation guidelines where it states monitoring not necessary for roosts of lower conservation significance.*"

*ii) Governmental/developer pressure (33% of responses)*

Many respondents perceived that there was governmental pressure to make protected species less of an issue for developers. Similarly, others thought that the pressure from developers to reduce the costs of biodiversity mitigation/compensation was the main factor for a reduction in post-development monitoring. For example, comments included:

> "*Pressure from government to reduce environmental constraints on developers.*"

> "*The government is worried about escalating costs for the developer and has become more lenient where monitoring is concerned.*"

> "*Inability to enforce monitoring and pressure to avoid delays to the provision of housing supply.*"

*iii) Lack of resources (23% of responses)*

Respondents perceived that a lack of resources in both LPAs and SNCBs meant that monitoring was often deemed unnecessary because it would be impossible to track or enforce. For example, comments included:

> "*Greater realisation that mitigation measures must be monitored and that this needs to be enforced, however the resources don't exist*."

> "*Lack of council staff resources/time to examine planning applications properly*"

*iv) Lack of experience (11% of responses)*

Respondents suggested that the considerable variability in staff experience within both SNCBs and LPAs contributed to a strict reliance on guidance rather than incorporating an understanding of the circumstances. Similarly, differences in experience between LPA staff (i.e. if a full-time ecologist was employed) resulted in variable levels of monitoring requirements being imposed. For example, comments included:

> "*Loss of expertise from the statutory sector. Advice often appears to come from a book rather than empathy or understanding of the circumstances*"

> "*It seems very much dependent of late whose desk an application lands on as to what they require in respect of monitoring*."

## 2.4 Discussion

Understanding the extent of mitigation and post-construction monitoring is important as it contextualises the scale of developments with the potential to affect bats in buildings. The 228 consultants interviewed in this survey handle over 5,000 cases a year involving the mitigation of bats within buildings. Given the respondents to the questionnaire represent only a subsample of the number of consultants currently working in the UK and Ireland, we can make a conservative estimate that there are a minimum of 10,000 cases of bat mitigation in buildings a year.

Overall, the clear majority of respondents felt they had inadequate evidence on which to base their decisions about mitigation; with a fifth of those perceiving that they had no sound evidence. This highlights the pressing need to establish a robust evidence base which can inform best practice.

This study found that bat boxes are frequently used as a mitigation measure (in 76% of cases), which is similar to that of Stone *et al*. (2013) who reported that boxes were used in 67% of cases. Although we did not ask consultants to distinguish between cases where boxes are used in isolation or in combination with other mitigation measures, given that boxes are frequently used as interim measures, it is likely that a high proportion of the cases described involved the use of boxes alongside additional mitigation features.

There was a perception amongst many practitioners that the requirement to monitor mitigation has reduced in frequency over the past five years; however, the reasons given varied considerably. There was a broad consensus that either governmental pressure or a movement to become ‘developer-friendly’ was responsible for the decline in monitoring. Reducing the cost implications of development was often thought to be the main cause. Given that post-development monitoring can often vary in duration (e.g. additional surveys can be requested if initial inspections do not find signs of the presence of bats), it is likely that developers want to avoid the uncertainty of non-fixed costs extending beyond their completion date.

The difficulty that SNCBs face in tracking or enforcing monitoring requirements was often cited as a cause of the decline in monitoring. Recent revisions to licensing procedures were thought to be primarily designed to reduce their administrative burden rather than achieve high standards and effective mitigation practice. Given the limited resources available to the SNCBs this is unsurprising, and may also explain why consultants felt that varying levels of experience amongst SNCB staff may also be responsible for variable monitoring demands.

The overriding theme recurrent across the questionnaire was that monitoring could often be perceived as an unnecessary expense and was therefore relatively easy to dispense with. It is therefore important to ensure that, on occasions where post development monitoring is conducted, that its explicit purpose is clear, and that the results contribute to both an understanding of mitigation success within the site and to the wider understanding of the effectiveness of mitigation.

## Chapter 3: The effectiveness of mitigation strategies for bats in buildings

The evidence base for current mitigation activities is largely centred on the 2004 *Bat Mitigation Guidelines* (Mitchell-Jones 2004). This document placed the UK ahead of most other countries globally in formalising an approach to bat mitigation, and provided useful generic technical advice on developing mitigation plans. Nevertheless, it was necessarily reliant on personal experience, and on untested, if intuitive, recommendations for mitigation strategies. Formal statistical assessments of data contained within ecological consultancy reports have been conducted within this study in order to update the evidence base for a range of widely-distributed bat species and to highlight data gaps for future assessment.

### 3.1 Methods

Case studies were obtained from a variety of sources. A request was made via emails to the CIEEM members' list, social media, and personal contacts, for case studies in which mitigation had been conducted to compensate for the damage or destruction of a bat roost within a building. Importantly, information was requested from follow-up monitoring so that an assessment of the efficacy of mitigation could be made. Case studies involving *Myotis* spp., common pipistrelles (*P.pipistrellus*), soprano pipistrelles (*P. pygmaeus*) and brown long-eared bats (*P. auritus)* were specifically requested, as these species are commonly encountered during developments involving buildings, and they have UK- and Ireland-wide distributions. Horseshoe bats (*Rhinolophus* spp.) were specifically excluded because, although they can form a high proportion of the case-load in some regions, particularly in south-west England and parts of Wales, it was considered that the evidence was much more established for these species than for any others (e.g. *Rhinolophus hipposideros*; Schofield 2008).

Ecological practitioners submitting project reports that fitted the criteria above were requested to either upload all their case studies, or alternatively to provide a random subsample of cases. This avoided the preferential selection of mitigation cases which show bias towards either the effectiveness or ineffectiveness of certain mitigation strategies. We were, however, unable to control for which ecological consultants provided us with data and there may be an association between the likelihood of uploading and mitigation success.

Initially, all of the documentation which comprises a European Protected Species (EPS) licence was requested, namely: licence application form, licence method statement, work schedule, any requested modifications to the application, action taken under licence (e.g. licence sign-off form, monitoring conducted), and any additional files that were relevant. However, following feedback from consultants that the process of compiling these files was too time-consuming, subsequent requests were changed to state that a minimum of the method statement and monitoring reports was required. Case studies were uploaded securely via a file-hosting service (Dropbox). Initially, an option to enter details via an online questionnaire was available; however, this was rarely used because of the time constraints limiting practitioner involvement, the difficulties consultants faced in compiling and extracting data from reports, and the extent of the information that was needed. Additionally, we requested access from SNCBs to case studies that had been submitted as part of EPS licence applications. The availability and accessibility of the data varied between the SNCBs:

*Department of Agriculture, Environment and Rural Affairs*: Monitoring of mitigation measures is rarely stipulated in Ireland. Consultants were therefore contacted directly rather than obtaining licence returns.

*Natural England (NE):* A 'Restricted Licence for reusing NE's Information and Data' was obtained from NE which allowed us to access their 'TRIM' database. This only contained data from 2013 onwards, as earlier case studies have not been digitised. This restricted the number of case studies we could obtain through this method, given that relatively few cases had undergone mitigation, implementation, and monitoring in this short time period. We searched 'TRIM' using an index of reference numbers, which listed case studies where licence returns were expected to have been submitted; however, there was considerable variability in the extent to which the expected licence documents were found within the database.

*Natural Resources Wales (NRW):* Case studies received from NRW consisted only of monitoring reports. Their pre-construction reports are either held in separate, individual folders within the NRW document management system and are difficult to retrieve, or are in paper format and would require hand-searches. NRW did not think it was viable to access any of these pre-construction records due to time pressures on their staff during 2017.

*Scottish Natural Heritage (SNH):* Monitoring of compensation measures is not typically secured through a licence condition in Scotland. When monitoring is undertaken, the results are not reported to SNH (Mackintosh 2016). Additionally, it was considered that, if post-development monitoring showed no uptake by bats, then remedial action would be extremely difficult to impose (B. Ross, Licensing Manager, Scottish Natural Heritage, *pers. comm*). Consultants were therefore contacted directly for case studies. Where relevant, case studies outlined in Mackintosh (2016) were also used to contribute to the meta-analysis.

Data was extracted from case studies using a standardised pro-forma. Where necessary, ecological practitioners were contacted for additional information to clarify any areas of uncertainty. Our NE restricted licence and associated data protection laws meant we were unable to contact either homeowners or consultants from case studies obtained.

Figure 3.1 shows the distribution of the case studies that were received from across the UK. Although replies were received from multiple consultants in Northern Ireland and the Republic of Ireland, following individual requests for cases, the consensus was that post-development monitoring was very rarely conducted in these areas.

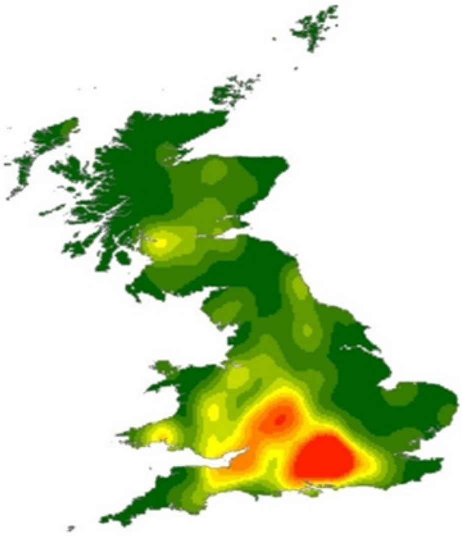

**Figure 3.1** Kernel density map of case study sites across the UK. Map based on case-study density within 20km grid square zones across the UK. Dark green areas of the map indicate the absence of survey sites, whereas light green, yellow and red patches indicate the areas with the highest densities of case studies received.

The effectiveness of mitigation strategies for bats within buildings was assessed in multiple ways to ensure that all the data provided was utilised fully to enhance the evidence-base. Within this study, an overview of the effectiveness of a variety of mitigation strategies is presented, the key mitigation features which increase occupancy and re-occupancy rates are identified, and the manner of collecting and reporting monitoring data and how it could be enhanced has been assessed.

## 3.2 *Before-after study*

The simplest way to evaluate the success of an intervention is to compare the number of individuals before and after mitigation to assess whether bat roosts are being retained within developments.

***Methods***

Only a subsample (n=90) of the submitted case studies were suitable for this analysis. The remainder were excluded because substantial methodological differences between the pre- and post-mitigation surveys precluded fair comparisons. Cases were included only where an assessment was made of the roost size, not just roost presence, in both pre- and post-development surveys, although it should be noted that estimates of roost size can be subjective. The difference between the number of individuals before and after development was formally tested using a paired t-test as the data conformed to a normal distribution. A $p$ value of $<0.05$ was taken as an indication of statistical significance. Analysis was split into cases where: i) roosts were destroyed and compensation in the form of either bat boxes or bat lofts was provided, and, ii) cases where roosts were modified because of re-roofing activities.

Common and soprano pipistrelle bat data was combined during the analysis of modified roosts due to the limited sample size (26 in total).

***Roost destruction***

In cases where a roost was destroyed and the mitigation strategy involved the use of either a new bat loft/house or bat boxes as compensation, paired sampled t-tests showed that there was a significant difference between the numbers of individuals recorded pre- and post-development for all bat species/genera (Table 3.1).

**Table 3.1** A comparison of bat populations before and after mitigation using a paired-sample t-test for cases where roost destruction occurred.

| **Species/genus** | **Sample size** | **t** | ***p*** |
|---|---|---|---|
| Brown long-eared bat | 49 | 5.06 | <0.001 |
| Common pipistrelle | 55 | 6.55 | <0.001 |
| Soprano pipistrelle | 41 | 3.01 | 0.005 |
| *Myotis* spp. | 12 | 3.69 | 0.004 |

The trends visible in Figure 3.2 demonstrate that relatively few case studies maintained or increased the number of bats present following mitigation; for example, only 10% and 7% of common pipistrelle and soprano pipistrelle roosts respectively maintained their size following development. In the absence of surveys during the maternity period, it can be difficult to determine whether a roost is used for breeding. Nevertheless, it is generally true that larger roosts are more likely to be used as maternity sites. For example a typical brown long-eared bat nursery roost contains between 10 and 30 individuals (Greenaway & Hutson 1990). It was found that only 19% of pre-construction roosts above this threshold (10 individuals) retained at least this number post-development, and 69% of these roosts did not retain bats at all following mitigation.

*Myotis* spp. roost sizes vary depending on species (Dietz *et al*. 2009); however, only four such case studies were received which contained more than 10 individuals in pre-construction roosts. None of these roosts retained nursery-level numbers of bats following mitigation (i.e. 10 individuals), and only one of these roosts retained bats.

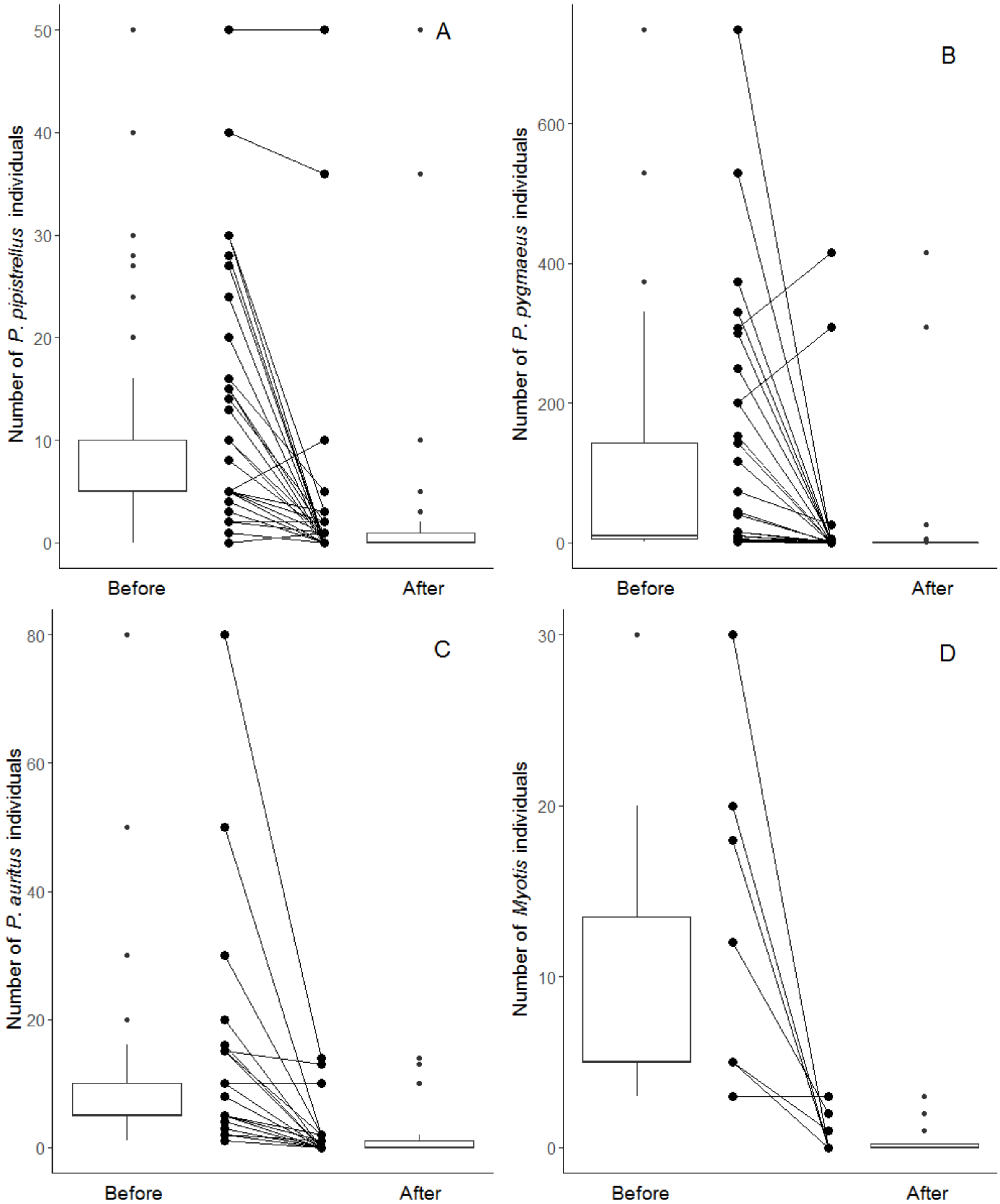


**Figure 3.2.** A comparison of the number of bats before and after mitigation in cases where the roost was destroyed for common pipistrelle (A), soprano pipistrelle (B), brown long-eared bat (C), and *Myotis* spp. (D). The boxplots represent the median (bold line), the first and third quartiles (top and bottom of box), the range (end of the whiskers) and outliers (dots). The paired dot plot (centre of the graph) represents the difference in population size for individual case studies before and after development. An outlier that went from 180 bats in pre-construction surveys to 200 bats post-construction has been removed from (A) for clarity.

*Roost modification*

In cases where roosts were modified primarily because of reroofing work, paired sampled t-tests showed that there was no significant difference in population size before and after development for either pipistrelles (n=26, t=1.13, p=0.27) or brown long-eared bats (n=21, t=0.40, p=0.69). Although only 12% of post-development pipistrelle bat roosts reached or exceeded pre-development size, over half (54%) of roosts retained occupancy of at least one individual following mitigation (Figure 3.3A). In contrast, 62% of case studies involving modification to brown long-eared bat roosts retained or increased the population size following mitigation (Figure 3.3B).

For pre-development brown long-eared bat roosts containing 10 or more individuals (which for this purpose we will infer to have been a maternity roost; Greenaway & Hutson 1990), 60% of post-development roosts retained at least 10 bats after undergoing reroofing.

In comparison, pipistrelle roosts could generally be split into two distinct categories as a consequence of the case studies we received: small roosts (range 1 to 10 bats) and larger roosts (range = 100 to 876 bats). Large pre-development roosts (containing greater than 100 individuals) retained similar numbers of bats following mitigation whereas smaller roosts (i.e. those containing up to 10 individuals) all failed to exceed ten individuals post development. This appears to highlight that larger, potentially important roosts from a conservation perspective, are being retained during roost modification whereas the smaller roosts which are less likely to be of conservation significance are not.

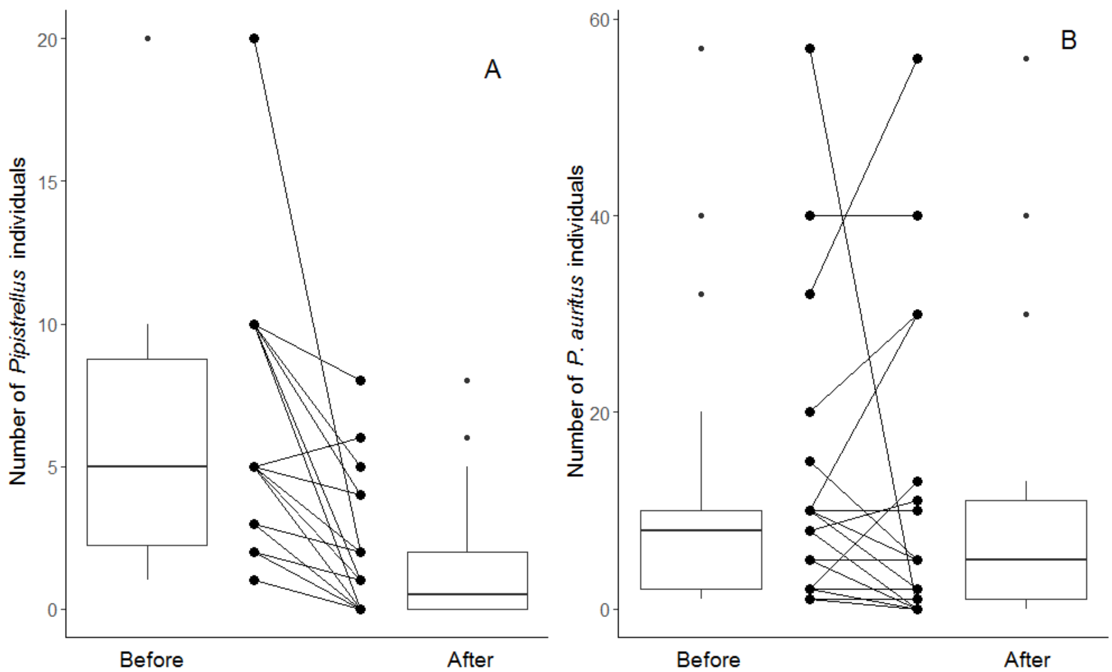


**Figure 3.3.** A comparison of the number of bats before and after mitigation in case studies where roosts were modified primarily because of reroofing work for pipistrelles (A), and brown long-eared bats (B). Outliers (four case studies) containing greater than 100 individuals were removed from (A) for clarity (Outlier 1: before 200, after 309; Outlier 2: before 876, after 507; Outlier 3: before: 100, after 0; Outlier 4: before 300, after 300).

### *Discussion*

The vast majority of case studies involving roost destruction resulted in a decline in bat populations, whereas populations were more likely to be retained at buildings where roosts were modified. Re-roofing can involve a relatively short period of disturbance for bats, particularly if conducted over a season when bats are seasonally absent, meaning bats can return to the same place effectively without interruption. It would be useful to contrast the length of time between successful and unsuccessful reroofing works; however, this information is infrequently reported in post-construction monitoring reports.

Although there is an evident negative trend across studies, it is important to qualify these findings with the following:

i) Surveying effort differed between pre-and post-development surveys with, on average, pre-development surveying events double those of post-development surveys (median = 2 surveys). Although on many occasions pre- and post-mitigation effort could differ due to factors including differences in the number of roost entrances, there was also relatively little consistency in the surveying methodology between pre- and post-development surveys (e.g. timing in the night, time of year).

ii) Observed changes in population size may not be causally related to any activities occurring at the roost, but instead be a consequence of changes in the wider landscape. For example, female pipistrelles may change their roosts because they are closer to attractive foraging sites (e.g. Bartonička *et al*. 2008; Feyerabend and Simon 2000). Roost uptake will therefore, in part, be dependent on how the landscape has developed during the mitigation process. Given that most cases considered in this study were relatively small-scale, it is unlikely that 'within the development boundary' habitat modifications would have dramatically altered foraging preferences; however, we cannot account for wider landscape modifications.

There were species-specific differences in the responses to mitigation, particularly between brown long-eared bats and pipistrelles in roosts that underwent modification. Brown long-eared bats returned to modified roosts in similar numbers to pre-mitigation levels in contrast to pipistrelles, which rarely attained similar levels. This may reflect a stronger roost loyalty in brown long-eared bats (Entwistle *et al*. 2000) or limited roosting options elsewhere for brown long-eared bats in contrast to pipistrelles. Pipistrelles are relatively robust to exclusion from roosts in houses and, in the short term at least, show no significant change in behaviour or foraging patterns following exclusion (Stone *et al*. 2015). Given the wide variety of alternative roosts that pipistrelles can use, ranging from individual roosts behind ivy on trees to substantial colony roosts in inhabited dwellings (Stone *et al.* 2015), it is likely that pipistrelles were roost-switching rather than returning to the modified roost. The probability of detecting bats during post-construction monitoring may therefore reflect roost availability in the surrounding landscape alongside the effectiveness of mitigation and compensation strategies.

## 3.3 *Factors influencing whether new bat roosts are used*

The creation of new or modified roosting space provides roosting opportunities not just for bats displaced during development but also for the local bat population more generally. The success of new roost creation was assessed, with the caveat that it is not possible to know (in the absence of studies that identify individuals) whether the usage is by displaced individuals or others in the wider population. The uptake of a roost will be dependent on a wide variety of factors including the availability of alternative roosts in the surrounding landscape. Similarly, many mitigation strategies include the provision of both a new bat loft and bat boxes. In the following analysis, we assess the success of bat lofts independently of whether any additional bat boxes were used. Analysis of bat box data is restricted to sites where bat boxes were used as the primary mitigation or compensation measure.

**Methods**

***The effectiveness of mitigation strategies***

Generalized linear models (GLM) with binomial error distributions were used to determine the relative success of different types of mitigation strategies and whether the extent of disturbance (i.e. destruction versus modification to the roost) could predict mitigation success. The presence or absence of bats of any species was used as the response variable. Survey effort was included as a covariate.

The results of the binomial models are presented by using the odds ratio (OR) which provides an indication of the relative importance of each predictor. An OR of 2.0 would represent a doubling of the relative probability of bat occurrence; an OR of 0 would represent no change in relative probability, and an OR of 0.5 would mean the odds were halved. We also present OR confidence intervals, which indicate the range of values within which the estimate would be expected to fall on 95% of occasions where the work was repeated multiple times. Where the confidence intervals exclude one, the result is considered statistically significant ($p$<0.05). Additionally, the relative importance of each parameter was assessed by performing likelihood ratio tests (Faraway 2005).

***Factors influencing whether new bat lofts are used***

GLMs with a binomial error distribution and a logit link (used when the dependent variable is categorical) were constructed to determine which characteristics of a bat loft influenced the retention of bats. The presence or absence of i) pipistrelles; and ii) brown long-eared bats, were used as the response variables within each of the models. Similarly, either Poisson or negative binomial models (dependent on model fit) were used to determine which bat loft characteristics influenced the number of bats present within a roost. The maximum number of bats (pipistrelles or brown long-eared bats) recorded during one surveying visit was used as the response variable within each of the models.

Clearly, large numbers of characteristics have the potential to affect the likelihood of a new bat roost being used. To keep the number of potential predictors within reasonable limits, the characteristics outlined in Table 3.2 were selected for analysis, based on recommendations within the Bat Mitigation Guidelines (Mitchell-Jones 2004) and a preliminary assessment of the characteristics most commonly reported within the method statements submitted by ecological practitioners.

**Table 3.2.** The characteristics of bat lofts assessed within this study.

| Characteristic | Description |
|---|---|
| Loft volume ($m^3$) | The length, width and height of the proposed bat loft. Volume calculated following Entwistle *et al*. (1997). |
| Number of compartments | The number of distinct (although joined) compartments within a loft (e.g. formed by internal baffles. |
| Within loft roosting options | Classified into distinct categories: Boards (e.g. rough timber boards mounted on battens along the ridge beam); Box (e.g. squeeze boxes to create additional roosting locations inside the loft); Crevice (e.g. crevices on the walls constructed of plywood separated by 19mm spacers); Multiple (where a combination of boxes, boards and/or crevice features are used). |
| Number of roost entrances | The total number of roost entrances installed to facilitate bat access into the loft. |
| Number of roost entrances types | The number of different roost entrance types (e.g. access under ridge tiles or built in bat tubes). Insufficient data was included within reports to enable us to assess the provision of flight entrance points. |
| Roost location | The provision of roosting opportunities within either i) a new building, or ii) the building where the identified roost was originally located. |

It is important to note that the ‘Number of roost entrances’ can also be interpreted as the number of crevices/roosting opportunities available for crevice-dwelling species, which frequently use these features as roosting locations as well as accessing the internal loft structure.

Survey effort (the total number of surveying periods including roost inspections, dawn and dusk surveys) was included in the models as a main effect. All predictor variables were tested for collinearity (Pearson correlation coefficient ≤ 0.6 in all cases). Imputation was used to replace missing data within case studies to avoid list-wise deletion of cases that had missing values. The ‘mice’ package in R Studio (R Studio Team 2016) was used to generate plausible values using predictive mean matching for continuous data and polytomous logistic regression for unordered categorical data.

Assessment of binomial models was conducted using OR (the probability of occurrence), and assessing the relative importance of each parameter by performing likelihood ratio tests. For Poisson or negative binomial models, continuous predictor variables were centred and standardised following Schielzeth (2010) to allow direct comparison of the size of estimated coefficients. Inferences on the effect of each parameter were made by contrasting its standardised estimate to other predictor variables to assess relative importance, and performing likelihood ratio tests to compare models by excluding each parameter in turn (Faraway 2005). Simulated draws (n = 2000) were undertaken to construct prediction plots from the estimated distribution of an explanatory variable, whilst all other model parameters were maintained at their median observed values. All models were validated by visual examination of residuals (e.g. plotting residuals versus fitted values to check for constant variance; Crawley 2012).

Descriptors of additional variables (e.g. the presence of artificial heating) were also presented, which were not reported in a sufficient proportion of reports to include with the formal models, but may have been important in determining the occurrence of bats post-development. It is important to note that the descriptors are intended to highlight mitigation characteristics which, although not statistically proven to be effective, may provide a focus for future data collection and analysis when sufficient evidence has been accumulated.

***Factors influencing the use of bat boxes***

Only a very small proportion of case studies specified the exact location where bat boxes should be positioned in pre-development method statements, or detailed which boxes contained bats during post-development monitoring. All bat boxes at a site were therefore considered collectively. Statistical analysis was conducted following the same procedure as for bat lofts but with different characteristics included (Table 3.3).

**Table 3.3. The characteristics of bat boxes assessed within this study.**

| Characteristic | Description |
|---|---|
| Location | The location of boxes on a) trees; b) on the outside of buildings; or c) a combination of these locations. |
| Mean volume | The mean volume of bat boxes used at the site. |
| Number of boxes | The total number of bat boxes used at the site. |
| Guidance | Yes/No – was guidance to developers (i.e. height/aspect of boxes) included within method statement? |

***Factors influencing the use of modified bat roosts***

Modifications to bat roosts occur frequently during reroofing work or similar. Statistical analysis was conducted following the same procedure as for bat lofts but with different characteristics included (Table 3.4).

**Table 3.4. The characteristics of modified roosts that were assessed within this study.**

| **Characteristic** | **Description** |
|---|---|
| Number of roost entrances | The total number of roost entrances retained or installed to facilitate access into the loft. |
| Differences in roost entrances | Difference in the number of roost entrances between pre- and post-development. |
| Roost entrance locations | Whether roost entrances were i) retained in the same location, or ii) moved to alternative locations. |
| Enhancement | The enhancement of the bat roost whilst reroofing work was ongoing (e.g. the construction of squeeze boxes) to increase roosting options. |

## 3.3.1 Results

***The effectiveness of mitigation strategies***

It was found that the probability of bats reoccupying a roost following modification were considerably greater than in cases where roost destruction occurred. The probability of bat presence following mitigation were just over four times greater within modified but retained roosts than within destroyed and newly installed roosting features (OR 4.1, 95% CI: 1.9, 9.4).

Both the type of roost alteration (destruction versus modification; log likelihood: -143.7, $\chi^2$ 14.6, $p < 0.001$) and the number of post-construction surveys (log likelihood: -136.5, $\chi^2$ 6.6, $p = 0.01$) were significant predictors of the presence of bats within the roost.

The predicted probability of retaining bats within a modified roost was 0.76 (95% CI: 0.61, 0.87) in contrast to a probability of 0.44 (95% CI: 0.36, 0.52) in destroyed roosts (Figure 3.4 A). Post-development surveying effort was also positively related to mitigation success; the predicted probability of determining bat presence within a roost was 0.72 (95% CI: 0.56, 0.84) when the roost was surveyed five times in contrast to a probability of 0.44 (95% CI: 0.34, 0.54) if only one post-development survey was conducted.

Similarly, the type of mitigation strategy deployed was significant in determining occupancy rate:

- The probability of retaining bats after reroofing were seven times greater than if a roost was destroyed and only bat boxes were installed (OR 7.0, 95% CI: 3.0, 17.4).
- The predicted probability of retaining bats following bat loft creation was 0.53 (95% CI: 0.43, 0.62) in contrast to a probability of 0.32 if only using bat boxes (95% CI: 0.22, 0.44; Figure 3.4B).

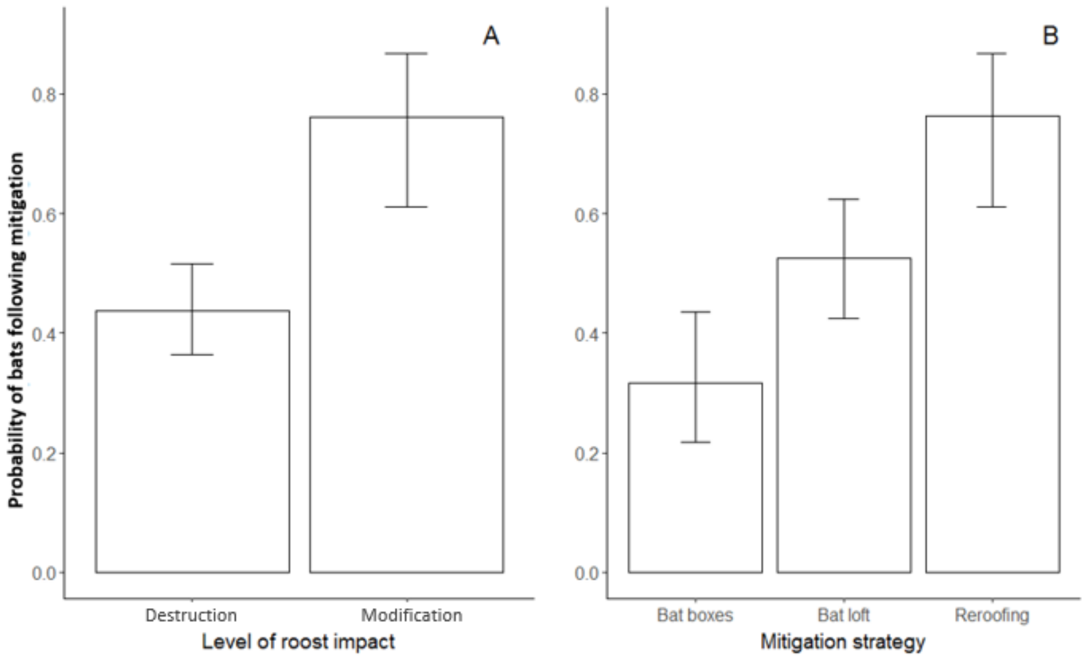


**Figure 3.4** Prediction plots of bat occurrence versus level of roost impact (A) and the type of mitigation strategy used (B).

It is evident that the success of mitigation is highly dependent on the strategy used and the extent of disturbance to a roost that occurs. In the following section, species-specific responses to each of the different mitigation strategies are assessed and the characteristics of a feature which influence its success are determined.

## 3.4 Bat lofts

### *Factors influencing whether new bat lofts are used*

This study assessed 112 mitigation case studies that included the provision of a bat loft. Of these, 71% involved the construction of a bat loft within a new building (most frequently above a garage); 19% within the same building; and 10% within an existing but different building from the original location of the identified roost. Newly created bat lofts were moderately successful at attracting bats with 52% (95% CI: 43- 61%) of lofts containing bats following development (Figure 3.5).

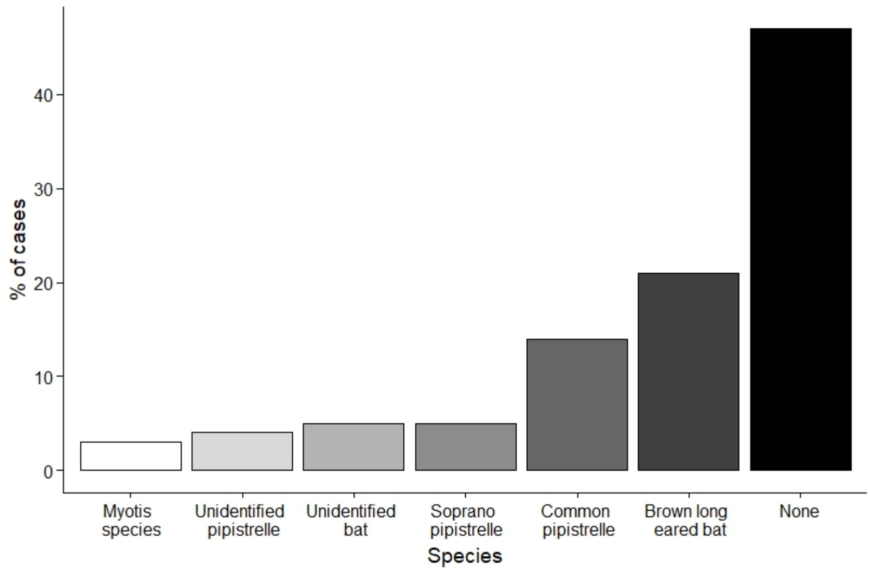


**Figure 3.5.** The percentage of cases which showed evidence of bats using purpose-built lofts following mitigation.

The number of bats using the bat lofts varied considerably by species, with brown long-eared bats having the highest mean number of individuals within the loft (Figure 3.6). The low numbers of pipistrelles (with the exception of one soprano pipistrelle roost) suggest that relatively few of these lofts have developed into maternity colonies. We also present results for the maximum approximate number of droppings found in one survey; however, it is worth noting that it is hard to both i) estimate the number of bats from the number of droppings, and ii) accurately estimate the number of droppings in a pile.

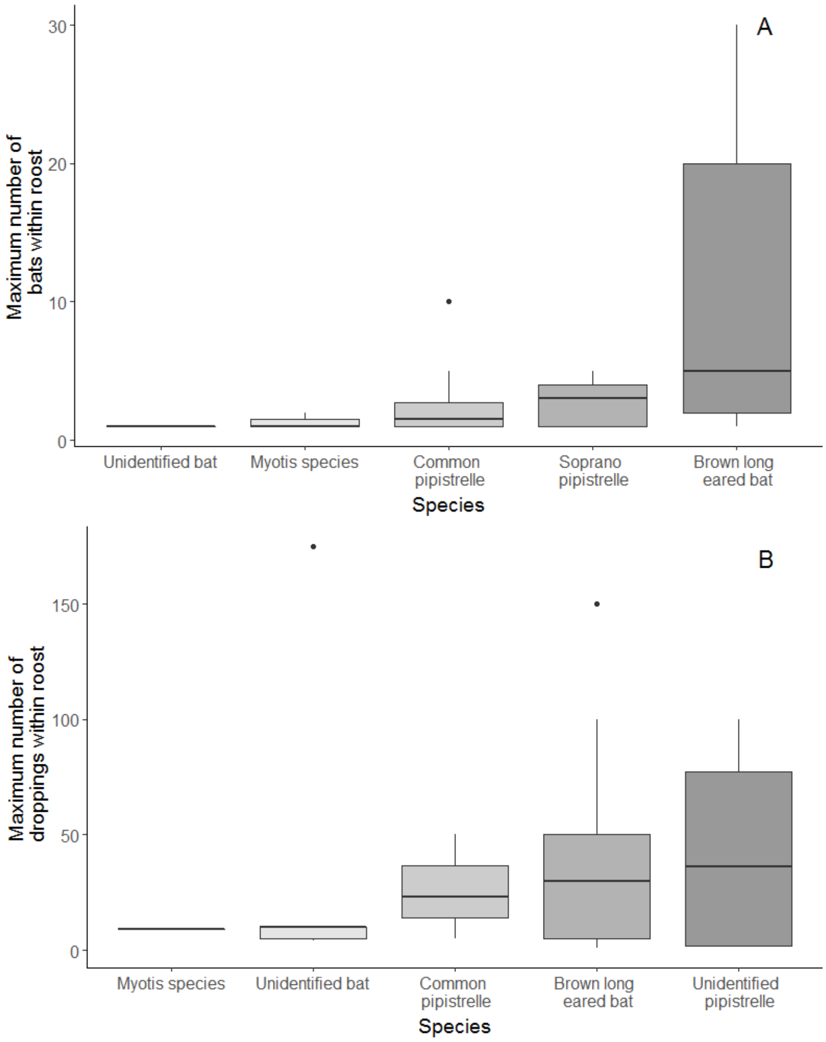


**Figure 3.6.** The maximum number of bats found within bat lofts following mitigation (A). A roost containing 416 soprano pipistrelles post-development is not visible within this graph due to the scale. The maximum number of droppings (approximate) found in one survey visit within bat lofts following mitigation (B). Two roosts which contained approximately 3000 common pipistrelle droppings and 1000 brown long-eared bat droppings are not visible within the graph due to the scale.

### *The characteristics of bat lofts*

Table 3.5 indicates the characteristics of bat lofts that were used by brown long-eared bats, pipistrelles or failed to be occupied by bats.

**Table 3.5** A description of the characteristics of new bat lofts following mitigation.

| Characteristic | Metric | Description of roosts | | |
|---|---|---|---|---|
| | | **Brown long-eared bat** | **Pipistrelle** | **Bats not present** |
| Height of roof space | Median (range) | 2.4m (1.5 - 4m) | 2.18m (0.2 - 4.6m) | 2.5m (0.3 - 4m) |
| Volume of roof space | Median (range) | $37m^3$ ( 18 - $264m^3$) | $24m^3$ (0.4 - $124m^3$) | $75m^3$ (0.3-$203m^3$) |
| Number of compartments | % of roosts with >1 compartment (range) | 67% (1 - 9) | 35% (1 - 9) | 49% (1 - 7) |
| Number of roost entrances | Median (range) | 2.5 (1 - 9) | 4 .5 (1 - 12) | 3 (1 -14) |
| Illumination in the roof space | Strategies designed to ensure loft is dark (%) | 21% | 15% | 17% |
| Presence of heating | Strategies designed to heat roost (%) | 33% solar heating, 6% heater | 33% solar heating, 6% heater | 26% solar heating, 7% heater |
| Other bat species in the roost | % of lofts used by other species | 37% (29% Pipistrelle bat; 8% *Myotis* spp.) | 27% (Brown long-eared) | N/A |
| Alteration of the roof space | Strategies specified to prevent access to loft (%) | 34% | 15% | 13% |

Comparable results to Entwistle *et al*. (1997) were found, in that brown long-eared bat roosts frequently contain more than one compartment (67% of roosts in our study versus 73% in Entwistle *et al.*). This is likely to be a consequence of compartments heating at different rates, thereby providing a range of temperatures within the loft. Pipistrelles were generally found in smaller volume lofts with lower heights than brown long-eared bats, which is unsurprising given that internal flight space is less of a requirement for pipistrelles.

***The probability of bat presence within bat loft***

This study found that the probability of pipistrelles occupying a new bat loft was strongly dependent on the number of created roost entrances (which for pipistrelles and other crevice-dwelling species may also act as roosting opportunities) and marginally related to the volume of the bat loft. The odds of pipistrelle bat presence within a bat loft increased by 29% for every additional bat entrance installed (OR 1.29, 95% CI: 1.08, 1.57). The probability of pipistrelle bat occurrence in a roost containing only one created entrance was 0.1 (95% CI 0.04, 0.21), whereas with 10 created entrances the probability was 0.56 (95% CI 0.26, 0.79) (Figure 3.7).

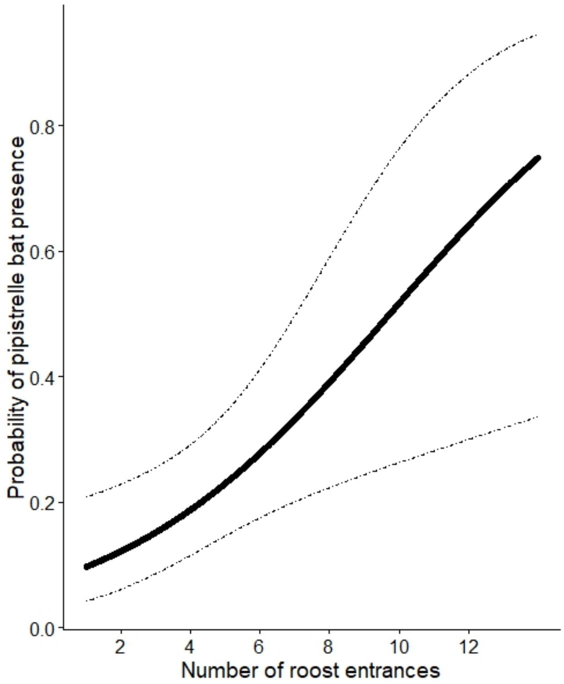


**Figure 3.7.** The predicted probability of pipistrelle bat occurrence at a new bat loft depending on the number of created roost entrances (potentially also roosting opportunities) available.

There was also a marginal negative relationship between the volume of the roost and the probability of pipistrelle bat occurrence. The odds of pipistrelle bat presence decreased by 1% with each $m^3$ increase in loft volume (OR 0.99, 95% CI: 0.98, 1.00).

The number of roost entrances was marginally significant (i.e. $0.05 > p < 0.1$) in predicting the presence of brown long-eared bats within lofts (log likelihood: -54.24, $X^2$: 2.87, p=0.09). The odds of brown long-eared bat presence within a loft increased by 21% with each additional roost entrance (OR 1.21, 95% CI: 0.97, 1.59) added.

The number of roost entrances was also a marginally significant predictor of the number of pipistrelles found within a bat loft (log likelihood:-57.39, $X^2$: 14.1, p=0.08). The sample size was considerably reduced when attempting to predict how loft characteristics determine the total number of bats, as the presence of bats was frequently determined either by droppings or emergence surveys which had considerable variability in surveying methodology.

Although the results indicate that increasing the number of created roost entrances will increase the probability of bats occurring post-development, it is likely that an upper limit will exist whereby additional entrances will create draught and light exposure to the loft. It was not possible to assess this maximal threshold given the constraints of not using an experimental approach (i.e. very few cases used more than six entrances – this is evident by the wide confidence intervals in Figure 3.7). The result should therefore be treated with caution and attention should be paid to ensuring any additional entrances do not impact the conditions (e.g. microclimate) of the loft.

### *Assessment of success of bat lofts by ecological consultants*

A relatively small proportion of bat loft case studies (n= 35, 31%) contained assessments of the success of mitigation strategies within their report. The assessments could be broadly split into four categories: 'not successful', 'no concern', 'partially successful' and 'successful'. The category of 'no concern' could be defined as cases where no bats had been found but no action was deemed to be required.

The one case study which defined itself as unsuccessful had determined bat presence within the roost, but stated that this was insufficient relative to the pre-development bat population. In contrast, 82% of case studies that perceived there to be 'no concern' had not detected bats during post-development monitoring.

The criteria on which success was judged by consultants were primarily:

i) mitigation strategies having been implemented correctly;
ii) activity surveys having recorded bats foraging in the area surrounding the roost which make it more likely that bats would start using the roost; and/or
iii) there having been insufficient time between mitigation and monitoring for bats to have colonised the loft.

Case studies which were considered partially successful had small numbers of bats present, whereas fully successful cases had reached or exceeded pre-development levels. A few case studies had scenarios where bats were still using the building, but not the intended mitigation: these were considered successes as the development remained a site of continued ecological functionality. It is worth noting, however, that retention of bats outside of the intended mitigation may have unforeseen consequences, such as the presence of breathable roofing membranes within the newly inhabited area. Very few case studies reported whether a maternity roost had developed within the bat loft; however, one barn containing 10 brown long-eared bats was considered likely to be used as a maternity roost as this number is within the typical size of a brown long-eared bat nursery roost (10-30 individuals; Greenaway and Hutson 1990).

## 3.5 Bat boxes

Bat boxes are frequently deployed around a site without the expectation for bats to be using all the boxes at any one time. Here, the effectiveness of bat boxes at retaining bats across a site is assessed.

### *Factors influencing the use of bat boxes*

This study assessed 119 mitigation case-studies that included the provision of bat boxes. A relatively low proportion recorded that the boxes were successfully used by bats (31%, 95% CI: 24%, 40%), with pipistrelles predominantly using the boxes (Figure 3.8). There was a relatively high number of cases where droppings were visually identified as pipistrelle bat droppings without the use of molecular verification.

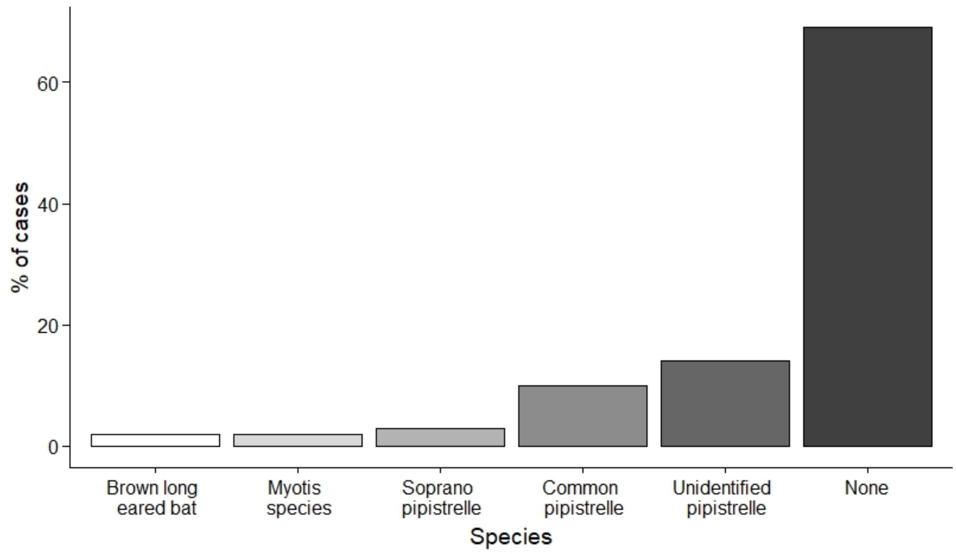


**Figure 3.8** The percentage of cases which retained bats within bat boxes following mitigation

### *The characteristics of bat boxes*

Bats were present at sites where a median average of five boxes were installed, in contrast to an average of three boxes at sites which were not occupied (Table 3.6).

**Table 3.6** A description of the characteristics of bat boxes per site following mitigation. Average volume of boxes is only intended for informative purposes to show the range of box sizes available rather than for analytical purposes.

| Characteristic | Metric | Description of mitigation | |
|---|---|---|---|
| | | **Bats present** | **Bats not present** |
| Number of boxes | Median (range) | 5 (1 - 32) | 3 (1-24) |
| Average volume (cm3) | Median (range) | 12,571 (5,598 - 60,000) | 11,764 (270 - 60,000) |
| Height (m) | Median (range) | 4 (3 - 5) | 4 (3 - 5) |
| Aspect | % of boxes facing broadly south | 63% | 54% |
| Location of boxes (95% CI) | Building (% occupancy)<br>Trees (% occupancy)<br>Mixture (% occupancy) | 22% (12-36%)<br>39% (28-52%)<br>23% (10-47%) | |

There was no difference in the height of boxes between sites where boxes became occupied and where they did not. Given that the majority of boxes are installed at heights recommended in current best practice guidelines (Bat Conservation Trust 2017b), there was relatively little range of heights that boxes were installed at. Sites where boxes were installed on trees appear to have a slightly higher (but non-significant, see below) probability of retaining bats following mitigation. Although the majority of bat boxes recommended were comprised of Woodcrete (>80%), it was not possible to test the effectiveness of wooden versus Woodcrete boxes formally given the limitations of how the data was reported (Chapter 4).

***The probability of bat presence within bat boxes***

This study assessed which features of bat boxes determined their occupancy by pipistrelles. Other species were found in an insufficient number of sites to be assessed individually.

At the site level, the greater the number of bat boxes deployed, the greater the probability of at least one of the boxes becoming occupied (Figure 3.9). The odds of bats occupying at least one box increased by approximately 7% (OR 1.07, 95% CI 1.00, 1.16) with each additional bat box that was deployed.

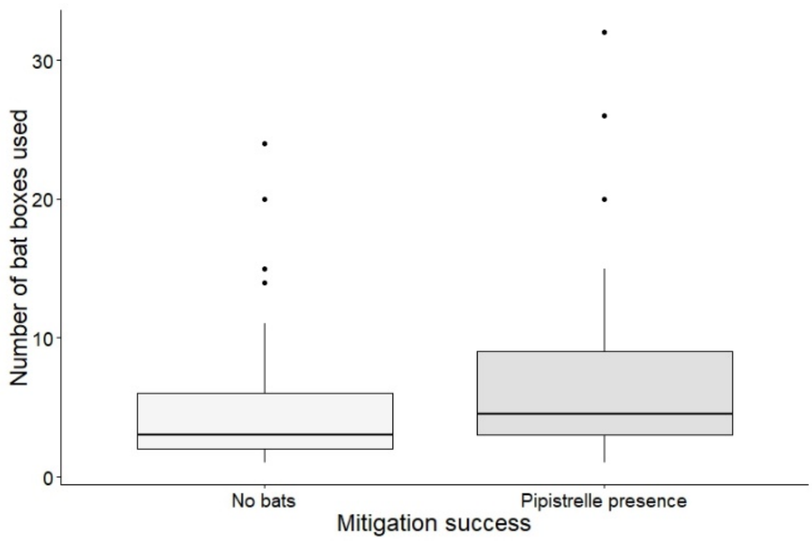


**Figure 3.9.** The relationship between the numbers of bat boxes deployed within a mitigation strategy and the occurrence of pipistrelles.

Additionally, there was a significant relationship between the number of bat boxes within a development and the number of bats contained within them (coefficient estimate: 0.4 ± 0.03, $X^2$ = 28.9, p=0.04). Despite its significance, the relatively small effect size (0.4) and the influence of one outlier on the result indicates that there is only a weak biological relationship.

***The use of multiple bat boxes***

Given the variable expense of adding additional bat boxes (cost dependent on bat box model used) to a mitigation strategy, it is pertinent to establish how the probability of uptake increases with each extra box installed. In Figure 3.10 there appears to be an exponential relationship between the number of bat boxes used as part of the mitigation strategy and the number of boxes which contain bats. When relatively low numbers of boxes were deployed (i.e. <20), only a small proportion of these became occupied, whereas when larger number of boxes were installed, the occupancy rate appears to increase. However, it is worth noting that even when a large number of bat boxes were deployed (i.e. >20 boxes), the occupancy rate remained relatively low (fewer than 50% of boxes were used). Given the wide range of box sizes and models are available it is likely that the relationship between occupancy and number of boxes will vary between box type.

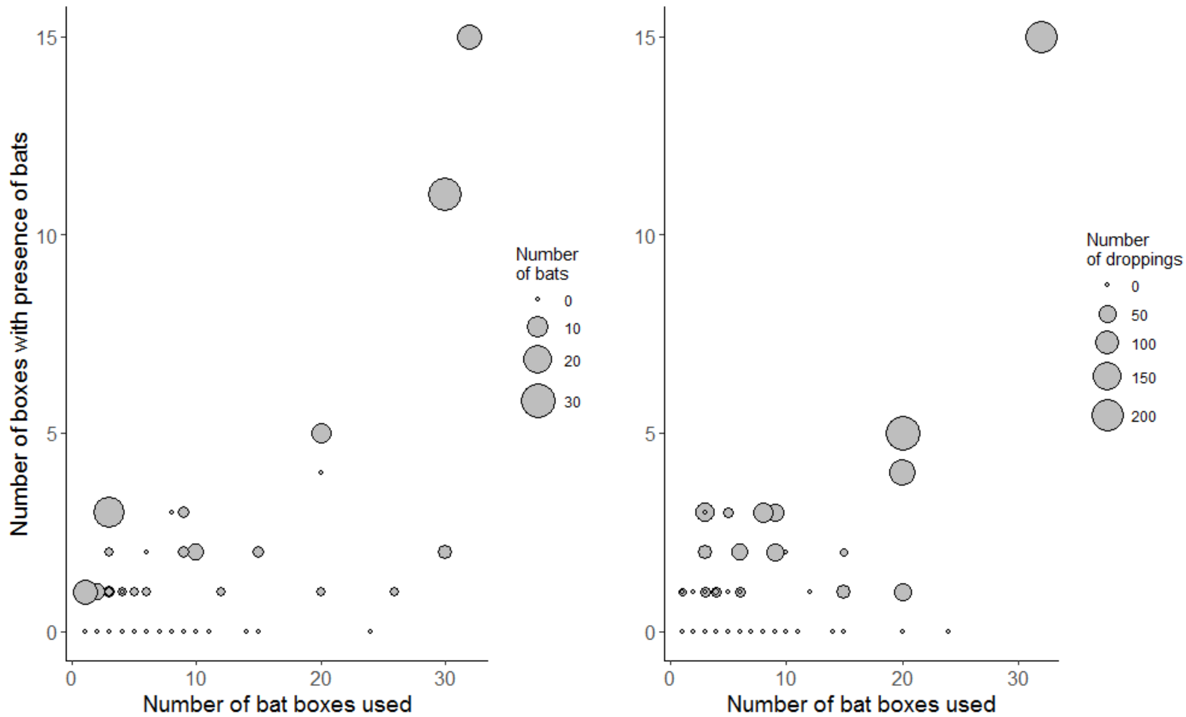


**Figure 3.10**. The number of bat boxes used and the number of boxes which became occupied. The size of the circles indicates the number of bats or droppings found across the site.

Larger clusters of bats (more than 10 individuals across a site) could not be predicted from the number of bat boxes deployed. For example, sites which only deployed one or two boxes on buildings retained 14 and 25 bats respectively post-development, whereas sites which deployed 30 and 32 boxes on trees retained 28 and 15 bats post-development. There was no difference in the make or model of the boxes used between these sites. This highlights that the siting of individual boxes at a micro-scale (e.g. alongside the edge of a woodland compared to in a housing estate with little vegetative cover), alongside the availability of alternative roosts in the surrounding landscape, are likely to be most important in determining bat box uptake.

***Discussion***

The number of bat boxes present within a site was the strongest predictor of whether bats would be retained following mitigation. Additional bat boxes may lead to i) an increased probability of a bat encountering a bat box, or ii) a wider variety of micro-habitats, which may attract a greater number of bats. Each additional bat box comes with the cost of purchase, bat box erection, maintenance and replacement over time.

Given the extensive use of bat boxes within mitigation, it is disappointing that it was not possible to assess the presence or absence of bats at the individual box level due to the lack of recording of these details (see Chapter 4 for further discussion).

## 3.6 Modified bat roosts

***The characteristics of modified bat roosts***

This study assessed 52 mitigation case studies where roosts were modified due to reroofing works. In 67% (95% CI: 54 – 79%) of cases, bats were retained following reroofing.

Table 3.7 indicates that the median number of roost entrances in reroofing cases is almost double that of new bat lofts (Table 3.5); this may explain the higher retention rate of roosts where there is displacement rather than replacement. This may be because, during reroofing work, additional time and effort is focused on identifying all previous entrances so that they can be retained or recreated. There was anecdotal evidence, within submitted case studies and from Table 3.7, that the retention of original timbers contributed to the success of new bat lofts. However, there was insufficient data to test this relationship formally. The inclusion within a method statement of whether new or original timber is to be used would allow the formal testing of its importance in retaining bat populations. Similarly, air flow or temperature data was rarely included in case studies despite anecdotal evidence that these may be important in determining bat presence.

**Table 3.7 -** A description of the characteristics of modified bat roosts following mitigation.

| Characteristic | Metric | Description of roosts | | |
|---|---|---|---|---|
| | | **Brown long-eared bat** | **Pipistrelle** | **Bats not present** |
| Number of roost entrances | Median (range) | 8 (1 to 10) | 6 (1 to 22) | 3 (1 to 10) |
| Difference in number of roost entrances (pre-post) | Median (range) | 0 (0 to 4) | 0 (0 to 4) | 1 (-2 to 2) |
| Location of roost entrances | % of sites which installed new roost entrances | 60 | 69 | 67 |
| Retention of old timber | % of roosts which retained timber | 33 | 20 | 6 |
| Alterations within roost | % of roosts altered to improve roosting potential | 31 | 53 | 12 |

***The probability of bat presence within modified bat roosts***

The probability of pipistrelles returning to a modified roost were found to be considerably greater if bat roosts were altered to improve roosting options as part of the reroofing work (log likelihood: -30.4, $X^{2:}$ 6.8, *p* 0.009). Although the individual strategies varied between case studies, enhancements included the re-instatement of the roof using handmade clay roof tiles to provide numerous natural crevices and the provision of rough sawn timber crevices and squeeze boxes. The odds of pipistrelle bat presence following mitigation were just over six times greater with enhanced roosts than roosts that were not enhanced (OR 6.1, 95% CI: 1.6, 27.7). The predicted probability of pipistrelles returning to a roost following enhancement was 0.59 (95% CI 0.3, 0.8) in contrast to a probability of 0.19 (95% CI 0.09, 0.37) in roosts with no enhancements.

There was a marginal but significant relationship between the number of roost entrances proposed and the probability of bats (all species) returning to the modified roost in comparable numbers to those found within pre-construction surveys (log likelihood: -27.3, $X^{2:}$ 3.1, $p$ 0.079). The odds of retaining comparable numbers of bats following mitigation increased by 16% for every additional roost entrance (OR 1.16, 95% CI: 0.98, 1.42) installed. The predicted probability of bats returning in comparable numbers increased from 0. 18 (95% CI 0.06, 0.45) when there was only one known entrance in contrast to a probability of 0.53 (95% CI 0.25, 0.79) when there were 12 known roost entrances. There were no significant predictors of brown long-eared bat occurrence within modified bat lofts.

***Assessment of success by ecological consultants for modified bat roosts***

A relatively small proportion of reroofing case studies (23%) contained assessments of the success of mitigation strategies within their monitoring return. Half of these concluded that there was ‘no concern’. In all of these cases, the target species was recorded in the roost, but it is also notable that the number of individuals had declined in all cases. High foraging activity recorded during monitoring surveys was also used as justification for the continual use of the site. Those case studies which considered the mitigation as a success specifically highlighted that the bats were using the same access points alongside returning in similar numbers. A few studies found that bats were using alternative parts of the building that had not undergone development with the premise that the wide availability of high-quality bat roosting opportunities explained the lack of retention of bats within the developed roost.

## 3.7 The occurrence of bats over time from mitigation

To determine whether i) the presence of bats or ii) the number of bats increases over time, sites were assessed where surveying had been conducted over multiple years. Only sites with comparable levels of surveying effort and monitoring methods (i.e. emergence surveys) which were undertaken between years were included, to allow for an accurate comparison. This considerably reduced the sample size (18 case studies in total); however, our results may prove indicative of trends and highlight the need for standardised, repeatable studies over multiple years. There were insufficient case studies to assess population change over time in maternity roosts.

It is evident from Figure 3.11 that the proportion of roosts that bats are identified as using increases over time; however, there is a marginal difference between years. Figure 3.12 demonstrates that there is considerable variability between sites in the time taken for roosts to accumulate either droppings or bats. It is important to note that these results are constrained by the relatively short period between implementation and monitoring. It would be expected that the number of bats and the quantity of bat droppings would increase incrementally over time. While the available evidence supports this for brown long-eared bat droppings and pipistrelle bat abundance, the relationship is less clear for pipistrelle bat droppings or brown long-eared bat abundance (Figure 3.12).

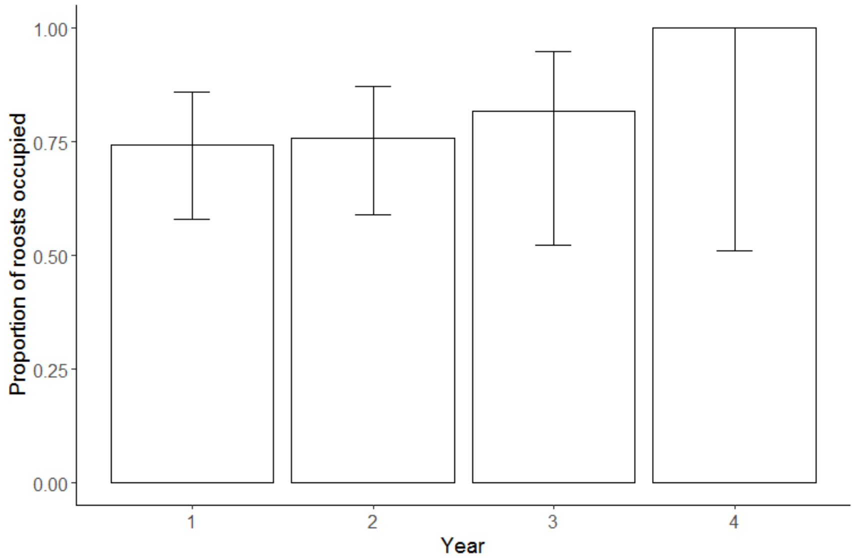


**Figure 3.11**. The proportion of roosts that showed evidence of bats within the four years that followed mitigation. Although all the roosts inspected in the fourth year contained evidence of bats, the wide confidence intervals indicate the uncertainty in this result due to the low sample size (n=4).

The wide confidence intervals in Figure 3.12 highlight the variability between case studies and reflect site-specific differences in retention rates and the length of time it may take to recolonise a roost. It is important to note that relatively few reports indicated whether droppings were removed from lofts or boxes between years. This makes it difficult to ascertain if an increased number of droppings is a sign of greater bat use over time. A few studies stated that sheets of paper were put down after a survey to accurately monitor changes in droppings; this is a more quantifiable method of measuring the accumulation of droppings and should form future best-practice guidelines. Additionally, bat droppings may not all accumulate within the loft space due to their roosting habits (e.g. within a cavity or between tile and roofing felt).

Like Mackintosh *et al* (2016), most monitoring returns received were within three years of mitigation, so it was not possible to investigate longer time-trends in roost occupancy.

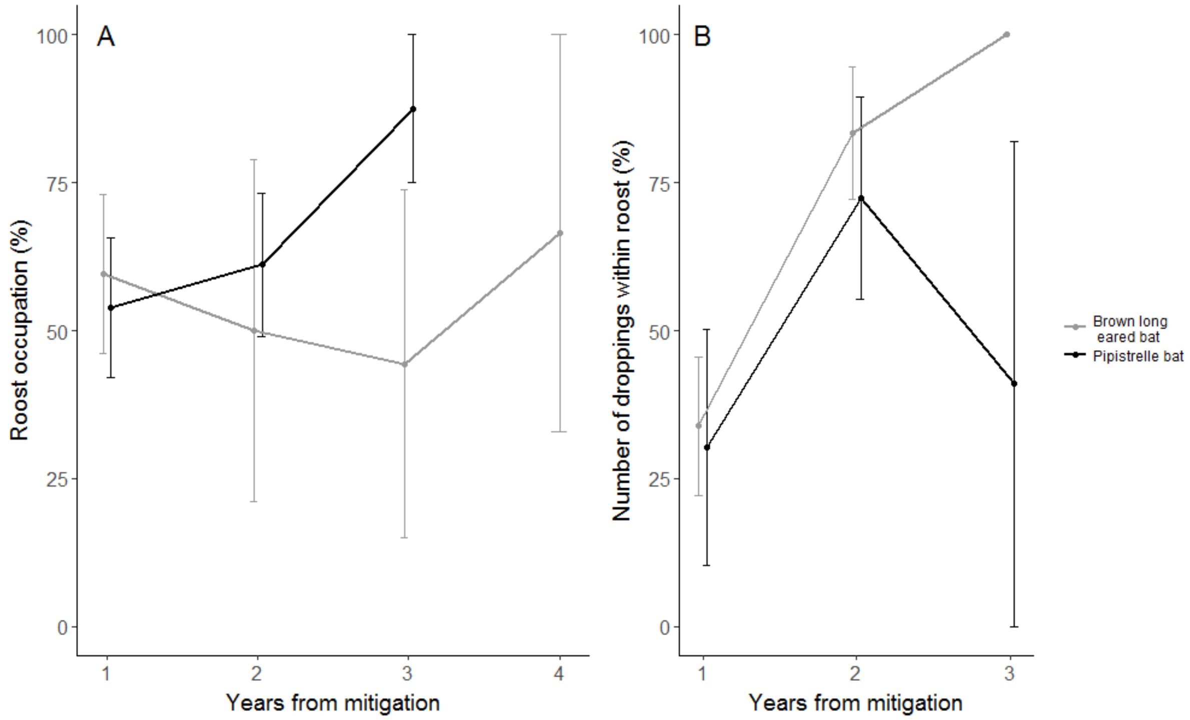


**Figure 3.12.** Roost occupancy against years from mitigation (A). For each site, a percentage was calculated by assessing the number of bats recorded within the roost during each post-construction surveying period against the peak number of post-construction bats found within the roost. Similarly for (B), a percentage was calculated by assessing the number of droppings during each survey against the peak number of droppings found at the site. Error bars indicate 95% confidence intervals.

## 3.8 Details within monitoring reports

Our method of extracting data from EPS licence applications was highly dependent on reports containing sufficient details to allow us to conduct statistical analysis. A sub-sample of monitoring reports (49 case studies) were assessed to determine what key information had been recorded (Figure 3.13). The date of survey (93%), personnel involved (80%) and weather conditions (68%) were the most frequently recorded within reports.

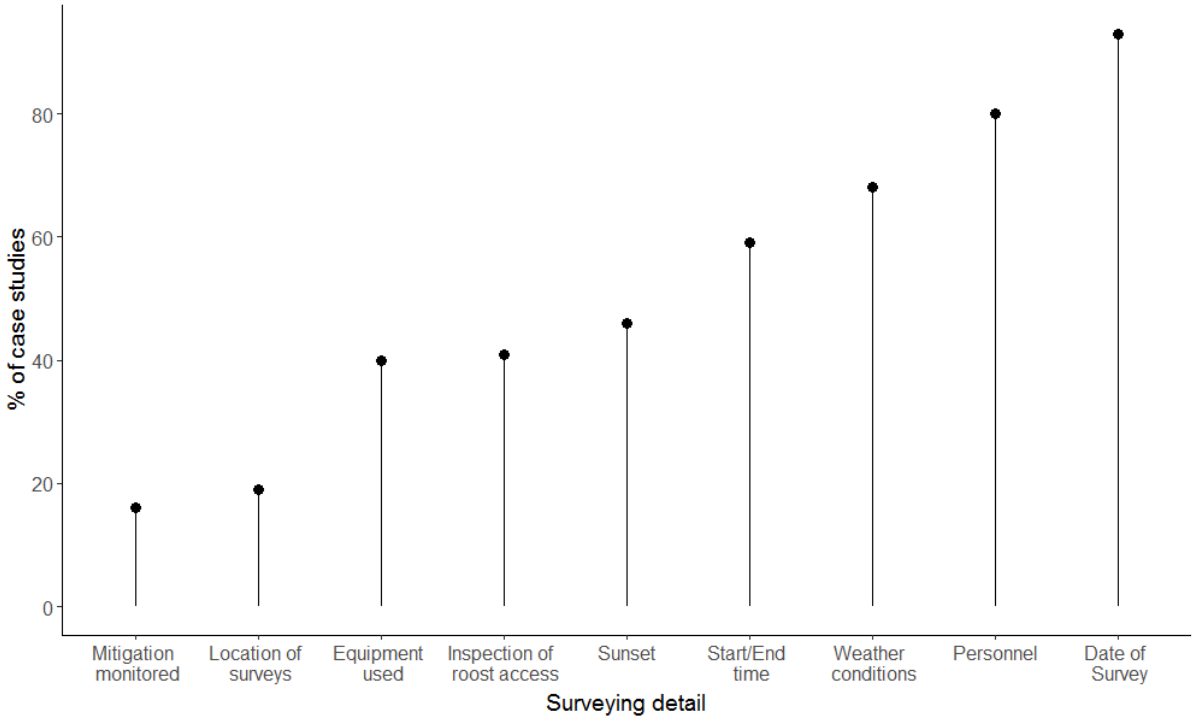


**Figure 3.13** The percentage of case studies which included a range of surveying details in emergence survey monitoring reports. 'Mitigation monitored' refers to whether the monitoring report identified which or how many mitigation features were visible during the survey (e.g. "all recently installed bat tiles were visible during this emergence survey").

Details of survey effort, such as the duration of emergence counts (start and end times), were only recorded in just over half the cases, making assessments of occupancy difficult given that detection rates are likely to increase with survey effort. Both the location of survey (i.e. what aspects/extent of the building were being monitored), and specifically which mitigation features were being observed, were reported in fewer than 20% of cases despite being critical for assessing the effectiveness of mitigation strategies.

It is understandable that method statements frequently omit the make and model of the bat boxes, their exact location, aspect or height above the ground, especially in larger developments. These decisions can often be taken at later stages of the development after a licence has been issued. However, post-development monitoring presents the opportunity to record this information. This will help consultants assess if the mitigation strategy has been implemented correctly, as well as collecting useful evidence to improve our knowledge of mitigation efficacy. Similarly, where multiple bat boxes have been deployed within a site, the reporting of which boxes contained bats is often vague. It is often impossible to determine whether boxes retained bats across seasons as the identity of boxes is not stated. Similar occurrences could be found in case studies involving the development or creation of multiple bat lofts within a site. Where a method statement refers to multiple lofts, then it is essential that monitoring reports use the same nomenclature on each occasion to ensure that specific locations can be matched up with survey results.

Cases were also encountered where thresholds of weather variables were reported (i.e. "the survey was undertaken in conditions suitable for emergence surveys such as temperatures above 8°C") rather than giving the exact measurements. Although this conforms to the surveying recommendations for current best-practice guidelines (Collins 2016), given the strong relationship between wind speed, temperature and bat activity (Russ *et al*. 2003), it is critical that Collins 2016 is followed and the actual measurements are recorded.

## 3.9 The use of bat activity to infer roost use

High foraging activity in the vicinity of roosts makes it likely that a mitigation feature is likely to be discovered and used by bats. Although most post-development emergence surveys also include reports of bats observed/recorded foraging in the vicinity of the mitigation strategy, these usually were not standardised in terms of survey effort or equipment with the pre-development surveys, preventing the formal comparison of the two survey periods. Where a roost inspection is not possible (e.g. no loft access is provided), or emergence surveys are difficult (e.g. multiple exits across a building) than bat activity surveys may be used to compare activity levels between pre- and post-construction; however, this is dependent on stringently following the same protocol to allow for a before-after comparison to be conducted. Additionally, while there is likely to be a relationship between the number of bats emerging and the number of bat passes recorded, this relationship is currently untested (and may be species-specific). The reporting of bat activity as either 'low', 'moderate', or 'high' by consultants within monitoring reports provides context to the extent of bat activity that was recorded (but see Lintott *et al*, *in press*); however, the lack of raw data meant that it was not possible to undertake any further quantitative assessment. Enquiries to consultants regarding access to data generally led to discussions around the difficulties in finding and compiling the data to make it accessible to others. We therefore recommend that standardising data collection and reporting during the licensing process will make the process easier for all involved (chapter 4).

# Chapter 4: Barriers and solutions to the lack of effective monitoring

Although this study has developed our understanding of the effectiveness of mitigation strategies, there are still gaps in the evidence base where data was either not collected or was reported in in sufficient detail to allow for analysis. Recommendations for improvements are outlined in this chapter and it is explained how these could facilitate the transition to a robust and transparent monitoring process

## 4.1 The purpose of post-development monitoring

Post-development monitoring is costly to developers and places an administrative burden on those responsible for ensuring that conditions of planning consent and EPS licensing are met. A lack of resources has therefore frequently meant that analysis of monitoring returns rarely occurs. It is therefore vital that there is clarity about the purpose of monitoring in order to ensure that the techniques used are proportionate, fit for purpose and deliver a positive result. For example, Natural England suggest that monitoring may be a means of "comparing population trends" before and after development (Natural England 2015), whereas for practitioners it may enhance their professional development by providing feedback on their decision-making.

If the main intention of monitoring is to determine the effectiveness of mitigation, then it is valuable to consider i) how success should be measured, and ii) what adaptive management actions, if any, should be put in place if the mitigation is found to be unsuccessful. The perception of what constitutes mitigation success is open to broad interpretation and could include any of the following definitions: retaining the same volume of roosting space; maintaining bat foraging activity around the roost; retaining the presence of bats within the same building; the occupancy of mitigation features by bats; and maintaining or increasing the population size within the roost. Each of these measures were used within case studies as justification that no further monitoring was required and that the development had not negatively impacted bats. For example, there were several cases where the discovery of bat droppings during a loft inspection was taken as sufficient evidence of use and so additional emergence and re-entry surveys were cancelled. Whilst this may be preferable to charging the client extra for additional surveys if the sole purpose was to confirm presence, these findings do not provide sufficient levels of detail to enable comparisons with pre-development population sizes. Where the threshold should lie is open to debate, for example, in a workshop hosted by the authors (Mammal Society Conference 2017), it was argued by audience members that, given the relatively short time between mitigation and monitoring, it would be unrealistic to expect populations to have returned to pre-construction levels. Although this viewpoint is understandable, it is worth questioning whether the timeframe for monitoring should be revised to ensure that comparisons between pre-and post-development bat numbers can be drawn. It may be that if monitoring is conducted within the first few years following mitigation, then the presence of the target species is sufficient as an indicator of mitigation success;

whereas in subsequent years attaining comparable population sizes would be expected. However, extending the period of post-construction monitoring would bring new challenges, such as obtaining access to buildings once ownership changes, getting the client to pay for the monitoring and the difficulties of calculating appropriate rates to charge for visits that may be 10 years in the future. Irrespective of where the threshold lies, we recommend that a measurement of success should be defined within the method statement during the pre-development stage of a project.

Given the perception that pressure from developers and the government is leading to a reduction in monitoring (Chapter 2), it may be that the explicit statement of the objectives of the monitoring would provide a more transparent basis for conducting post-development surveys. The inclusion of success criteria within the method statement would also allow an action plan to be developed if monitoring highlights a cause for concern. This ensures that remedial work is outlined from the outset, providing both a transparent cost to the client and a coherent purpose for undertaking post-development monitoring.

It is worth noting that the options available for remedial work will vary depending on the mitigation features used. For example, it is relatively straightforward to relocate or reposition a bat box, whereas if a bat loft has been constructed following best-practice guidelines, internal conditions ( temperature, light levels and humidity) are acceptable, and the external context (lighting, connectivity) is correct,  there may be relatively little modification that can usefully be made. In this case, given the importance of bat loft entrances, it may be that remedial action just involves the inspection of roost entrances to ensure they have remained clear and unlit. Alternatively, remedial action may not be considered necessary, regardless of the occurrence of bats, but by stating this at the pre-development stage, it gives the SNCBs and LPAs sufficient detail to assess these recommendations.

## 4.2 The standardisation of data collection and reporting

The extent of analyses that we could conduct were constrained by i) the number of  case studies we were able to obtain, and ii) a lack of detailed information within the case studies. Here, we outline why this might have been the case, and what strategies can be implemented to help build the evidence base in the future.

*The lack of case studies*: Consultants often cited a lack of time and difficulties in finding all the required information (e.g. collating reports from different members of staff who were involved in varying stages of the project; filing systems that meant that method statements were separated from follow-up monitoring data; older data being archived etc.) as the primary reason why they were unable to contribute to the project. It is therefore evident that the most appropriate time to capture this information is during the licensing process itself, as the SNCBs have the authority to require the relevant data to be submitted. Given that monitoring data are not currently assessed by the SNCBs (who also have time- and resource-constraints), then a satisfactory solution may be to adapt the current submission system to capture data more effectively; a process which should also assist the SNCBs in discharging their duties to report derogation licences and their consequences under Section 17 of the Habitats Regulations. The mechanism to enable this is discussed below.

*The lack of detailed information within licence returns*: This issue has frequently been highlighted as a problem, for example Stone *et al*. (2013) noted that they were unable to determine whether mitigation was effective because of "inadequate and inconsistent post-development data on licence return forms". Their study assessed licence returns from 2003 to 2005, and it is of concern that little appears to have changed in the intervening period. The development of an integrated electronic submission system that links data on the pre-development surveys, proposed mitigation strategy, implementation and post-development monitoring is therefore strongly recommended. This system would capture quantitative data that are comparable between cases and that can be analysed and assessed periodically.

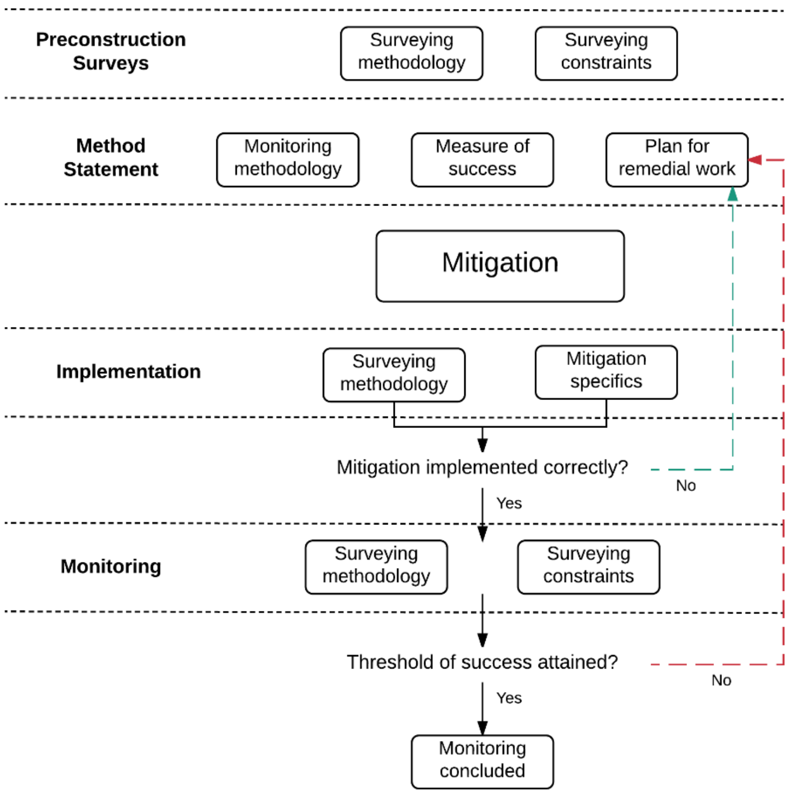


**Figure 4.1** Simple schematic illustrating the information that should be collected and reported to provide context for post-development monitoring. This includes comparable information between pre- and post-construction surveys, a method statement which includes details of the monitoring methodology and a measure of success, and a feedback mechanism to implement remedial work if either mitigation is not implemented correctly or the threshold of success is not attained. It should be noted, however, that some projects will not obtain the threshold of success even if all mitigation has been implemented as recommended; this should be judged on a case-by-case basis.

**Key recommendations**

1) Pre-construction method statements should include recommendations for post-construction monitoring strategies and a definition of what will be considered successful.

2) Where possible, assessment of implementation as per the mitigation/compensation strategy should be conducted as soon as possible following construction. Conversely, delaying post-construction monitoring by as long as possible will provide a better assessment of mitigation success.

3) Post-construction monitoring should replicate the methodology of pre-construction surveys as far as possible (e.g. survey type, seasonality, surveying effort).

4) The level of detail collected and reported during post-construction monitoring should match or exceed that of pre-construction surveys.

5) Post-construction monitoring should be used to collect additional information regarding mitigation strategies deployed, for example the make and model of bat boxes used, their location, aspect and height.

6) The development of an appropriately structured integrated electronic submission system that links data on the pre-development surveys, proposed mitigation strategy, implementation and post-development monitoring will increase the robustness of the evidence-base.

**Conclusion**

Bats are facing an unprecedented threat from rapid urbanisation and the potential loosening of environmental protection afforded to them. Evidence-based mitigation is therefore key to efficiently but effectively conserving bat populations at local, regional and national levels. The constraints on accessing or interrogating data to build the evidence-base should be addressed as a priority. An online system, set up to capture and securely store mitigation data will benefit SNCBs by providing an immediate and clear indicator of monitoring success, will contribute to a greater understanding of how best to undertake mitigation, and will provide consultants with the evidence to undertake effective mitigation.

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# Appendix 1: Questionnaire

This questionnaire was distributed to ecological practitioners in 2017 to further our understanding of the extent that post-development monitoring occurs (Chapter 2)

**Please restrict your answers to projects within the last 5 years which have involved bats roosting in buildings. Estimates are suitable for all answers. All answers will be treated anonymously.**

1) Please indicate if your responses will reflect:

i) Cases that you have personally led.

ii) A summary of cases undertaken by your company office.

iii) A summary of cases undertaken by your company.

2) What % of your projects included bat mitigation?

3) What % of these had an EPS Licence?

4) Approximately how many projects relating to bats in buildings do you deal with a year?

5) In your opinion, does the evidence base exist to enable you to make informed decisions on best practice mitigation strategies?

*Yes, Partly, No*

6) In what % of projects, has mitigation specifically addressed concerns about cumulative impacts at a landscape scale?

7) What % of mitigation strategies involved bat boxes?

8) As an estimate, what % of mitigation projects had follow-up monitoring recommended as part of an EPSL or planning application?

9) If mitigation occurs, have you been able to secure a requirement to monitor through the EPS licence or condition of planning?

*Yes, No*

10) Have you ever encountered a situation where you have *recommended* monitoring, and the client is willing to pay for it ***BUT*** a Statutory Nature Conservation Organisation or Local Authority has deemed it unnecessary?

*No* *Yes- stripped out by SNCB* *Yes-Stripped out by LA* *Yes – Stripped out by both*

10a) Do you think this problem is getting worse over the last 5 years?