# BEARING WITNESS FOR WILDLIFE:

# BAT ROOST MITIGATION PROJECT REPORT

completed by

Bat Conservation Trust

commissioned by

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# Executive Summary

*Introduction*
This report provides the results of BCT's Bearing Witness for Wildlife Bat Roost Mitigation Project, which was funded by the Esmée Fairbairn Foundation.

The project aimed to investigate the implementation and effectiveness of bat roost compensation and mitigation measures applied during development projects in England and Wales. All projects that were used for this review were subject to a derogation licence from the relevant licensing body and were completed between 2004 and 2014. Only projects involving common pipistrelle (*Pipistrellus pipistrellus*), soprano pipistrelle (*P. pygmaeus*), brown long-eared bat (*Plecotus auritus*) or *Myotis* species bats were included because these are the most common species involved in licence applications.

*Sources of case studies*
Development projects meeting the criteria outlined above were initially identified by Natural England, Natural Resources Wales and ecological consultants. Site owners were contacted by these organisations/individuals to request their participation in the study and thus access to their sites for bat surveys to be carried out by BCT.

*Baseline data*
From licensing documents we identified 409 bat roosts that had been directly or indirectly affected by developments in 119 buildings across 71 sites distributed across England and Wales. Of these, the number of low (non-maternity) and high (maternity) status roosts respectively for the different species was 118 and 15 common pipistrelle, 68 and 25 brown long-eared bat, 42 and 11 soprano pipistrelle and 42 and 5 *Myotis* species. In addition there were 50 low status roosts attributed to *Pipistrellus* species and a small number of low/high status roosts of other species or unknown species. Maternity roosts accounted for 14% of the sample in total but were distributed across 42% of the sites. Most were smaller domestic sites, 87% required planning permission for the proposed works and all were in rural or semi-rural locations.

*BCT monitoring surveys*
During the summers of 2017 and 2018 we carried out inspection and emergence surveys at these 71 sites to establish if proposed mitigation and compensation had been applied as specified and also if bats had returned to these sites post-development.

*Implementation*
The implementation of 2,333 proposed new roosts and access points was assessed; 61% were installed precisely as proposed, 19% deviated from what was proposed, 11% were absent and 1% were damaged. The remaining 8% were enhancements rather than compensatory roosts. No relationship was found between implementation and the number of provisions or the ecological consultant involved. It is likely that the type of mitigation proposed was the main influence on implementation. More complex structures (e.g. loft voids) were more likely to deviate from what was proposed than less complex structures (e.g. access points and bat boxes). However, larger features were less likely to be absent in comparison to smaller features.

*Effficacy - General*
During our surveys we recorded 208 bat roosts. Of these, the number of low (non-maternity) and high (maternity) status roosts respectively for the different species was 60 and 2 common pipistrelle, 42 and 1 brown long-eared bat, 48 and 5 soprano pipistrelle and 14 low status roosts of *Myotis* species. In addition there were a small number of roosts of other species or unknown species. We defined 8 different conservation outcomes following development and found, for example, that 14% of sites did not attract bats back at all, 86% of sites attracted some bats back but only 13% of sites maintained or increased abundance for all target species.

Only 18% of new roost and 8% of new access points were used by bats. Retained roosts (25%) and adapted roosts (52%) were used more frequently by bats than new provisions. Although it may be expected that retained roosts would be more effective than adapted roosts, most of the retained roosts were used originally only by individual or small numbers of *Pipistrellus* species bats, which turned up elsewhere on these sites rather than in the retained roosts. The adapted roosts catered for larger colonies, which were perhaps more faithful to these sites and thus returned to the adapted buildings.

When looking at different types of roosts, internal small cavity roosts were generally less successful in attracting bats back than external small cavity roosts and voids. There was a highly significant difference in the selection of broad roost types between species; *Pipistrellus* species favoured small external cavities and brown long-eared bats favoured voids.

We divided the roost types into 10 different subgroups and found there was a significant difference between bat occupancy rates for the different subgroups. Wall top gaps showed the highest occupancy rates at 40%, followed by wall-mounted bat boxes at 36%. The lowest occupancy rates were shown by gaps in stonework and brickwork (only 2% occupancy) and internal panels and boards (10% occupancy).

*Efficacy – Loft Voids*

When looking specifically at loft voids, none of the 13 new lofts were used by bats, 55% of 20 adapted roosts were used by bats and 65% of 37 retained lofts were used by bats. A significant difference between baseline and post-development monitoring counts for brown long-eared and *Myotis* species was observed. No relationship was observed between temperature and the number of bats but relationships were observed with the number of small internal cavities and the height/volume of the loft. The highest bat loft was 6m in height and no bats were observed in any lofts less than 1.5m in height.

*Efficacy – Bat Boxes*

Bat boxes were the most frequently deployed provision, being installed at 45 of the 71 sites. From a total of 270 boxes, 20% were occupied by bats. External wall-mounted boxes had the highest presence rates (36%) in comparison to tree-mounted (17%), wall integrated (15%) or internal wall-mounted (13%) boxes. Common pipistrelle was most frequently recorded in external wall-mounted boxes or integrated boxes compared to soprano pipistrelle, which more frequently occurred in tree-mounted boxes. The four most popular models of bat box used by consultants were all Schwegler; bat presence was highest for bats (all species combined) in the 1FF and lowest for birds. Birds were not found in bat box designs where the apertures were less than 17mm wide. No relationships were found between height and presence/absence or numbers of bats or between orientation and presence/absence (not enough count data to test relationship with orientation and numbers of bats).

*Efficacy – Access Points*

The majority (94%) of occupied roosts were accessed using only a single access point (note that this includes bat boxes, which can only be accessed using a single access point), the remainder were accessed using only 2 or 3 access points despite more being available. No relationship was found between the number of access points and either use-rate or maximum bat counts. Entrances to bat boxes were the most frequently used (20%), followed by wall tops (11%). The least frequently used entrances were stonework gaps (1%) and bat tiles (0%). A highly significant relationship was found between bat-use and aperture width – the most frequently used for all species had aperture widths of 13-22mm. The height of access points showed a significant relationship with bat presence, with increasing occupancy rate up to 4m. It was observed that nearly half of all confirmed access points were adjacent to a corner or overhang, with this appearing to be more important for soprano pipistrelle and brown long-eared bat compared to common pipistrelle and Myotis species.

*Efficacy – Overall*

Whilst we have highlighted some statistically significant findings through our work what is less clear is the site-specific variation. We observed that bats tended to return to sites when the mitigation/compensation most closely mimicked what was lost. This makes it extremely important to collect adequate baseline data about roosts and provide like-for-like provisions.

*Habitats and Lighting*
Only 10% of Method Statements in the study predicted impacts from lighting but our surveys found 32% of sites where light levels were considered to reduce the efficacy of the roost mitigation provided. Permanent or temporary habitat losses were predicted in only 11% of Method Statements and 18% recommended habitat creation or enhancement, which was only applied in just over half of cases. It was difficult to establish the impacts of lighting and habitat change on sites due to the lack of baseline information available.

*Post-development Monitoring*
Of the 71 sites, post-development monitoring was fully completed at 37%, partially completed at 24%, cancelled at 31% and not proposed at 7%. The higher the number and the longer the duration of proposed monitoring surveys, the less likely they were to be completed. If the proposed monitoring included night-time visits, the likelihood of monitoring being completed also decreased. Safeguards to secure monitoring had little influence on the implementation of monitoring: 44% of sites with safeguards had the monitoring cancelled altogether. The effect of licence expiry date is unclear but may be influential. Only 14% of sites specified some form of remedial action resulting from monitoring.

Looking at the efficacy of monitoring, night-time surveys were the most effective at detecting bats in smaller, external cavitites whilst smaller, internal cavities and void roosts were best detected through daytime inspection of both day- and night-time surveys. The more survey effort expended the greater the number of bat roosts found, up to three visits, after which this levelled off. Most effective provisions had been occupied within two years following completion, but roost occupancy did continue to increase over a longer time period up to around five years.

*Conclusion and Recommendations*
This study furthers our knowledge of how EPS licence conditions are implemented and the efficacy of different mitigation and compensation measures. It is positive that 61% of sites showed implementation exactly as specified in the licence and that 86% of sites attracted bats back. However, it is clear that further work is needed to improve the way we mitigate and compensate for roost and habitat losses during development and that a particular focus is required for some species, in particular brown long-eared bat.
This report presents a series of recommendations following each chapter. These include recommendations for species-specific mitigation/compensation, new guidance, changes to licensing systems and processes and further research. A key recommendation is that the mitigation hierarchy should be applied consistently because the clear pattern is that bats are more likely to return to retained/modified/adapted roosts than entirely new ones. Another significant recommendation is for reform to licensing processes to facilitate the collection, collation and storage of pre-, during and post-development data to enable future analysis of implementation and efficacy. Currently a huge amount of data is locked into consultant's reports and licence applications which, if unlocked, could improve our understanding of outcomes for bats. Improved data collection and collation should be coupled with improved systems for compliance checking and enforcement to increase levels of implementation of both mitigation/compensation and, importantly, post-construction monitoring.


# Acknowledgements

We would like to thank the Esmee Fairbairn Foundation for providing funding for this project. We are grateful to Natural England and Natural Resources Wales and all the ecological consultants for isolating licence cases that fitted our criteria, providing us with relevant documentation and contacting roost owners on our behalf.

We would also like to thank the roost owners for their assistance and relevant documentation and for giving us permission to access their sites for survey.

# 1.0 Introduction

## 1.1. Background to this work

A diverse range of human-driven impacts continue to threaten bat populations throughout Europe (Battersby 2010). Although recent studies indicate that several UK bat species may be recovering from the significant declines believed to have occurred in the 20th century, population figures are nonetheless far from historic levels (BCT, 2019). One of the most prominent threats to bats is considered to be the loss of roost sites (Entwistle *et al.* 1997; Mickleburgh *et al.* 2002). Jenkins *et al* (1998) conclude that roost sites are one of the most important features for temperate zone bats. They provide protection from adverse weather conditions, predators, parasitism, promote energy conservation and serve as sites for mating, raising young, hibernation and social interaction (Jenkins *et al* 1998; Mering and Chambers 2014; Ngamprasertwong *et al.* 2014).

Bats are unlikely to select roost sites at random (Entwistle *et al* 1997, Jenkins *et al* 1998, Carr *et al* 2018). Entwistle *et al* (1997) demonstrated that *P. auritus* may base roost selection on specific building attributes and surrounding habitat features, particularly warmer and more complex loft voids in older buildings that are lined with sarking. Indeed, bats are likely to select roost sites based on numerous factors including species-specific elements such as mode of flight and social behaviour, but also their life-stage, the season, local competition, climate, local roost density and foraging availability (Meddings *et al.* 2011, Mering and Chambers 2014). Such selection preferences are likely to enhance bat fitness and survival (Jenkins *et al* 1998).

Studies indicate that maintaining species populations and distributions may be constrained by the limited availability of suitable roost structures (Entwistle *et al.* 1997). A study by Boyd and Stebbings (1989) concluded that roosts may be a limiting factor for species such as *P. auritus*. Many UK bat species rely on roosts in man-made buildings (Dietz *et al.* 2009), possibly because they reduce predation risk and offer energetic and social benefits to bats in the temperate zone (Voigt *et al.* 2016). However, this also increases the likelihood of disturbance and conflicts with human occupants and developers (Briggs 2004, Zeale *et al.* 2016, Mering and Chambers 2014, Stone *et al.* 2015a, Voigt *et al* 2016). Indeed, the building development and maintenance sector accounted for most bat crime incidents investigated by the Bat Conservation Trust's Investigations Project in 2017 (BCT 2018). Roost exclusion and removal activities like this may negatively impact bat reproductive success (Stone *et al* 2015a) and cause population declines (Flaquer *et al.* 2006). Furthermore, developmental pressures are predicted to increase with increased urbanisation and housing demands from a growing UK population (Lintott *et al.* 2016; Mackintosh 2016), as well as a potential loosening of environmental protection (Lintott and Mathews 2018) or reduced government funding (Kerslake, 2019).

UK bats continue to benefit from comprehensive legislation that protects their roosts and the animals themselves from damage, destruction and harm (BCT 2018). It is likely that such protection has reduced the level of human disturbance on bats (BCT 2019) and this was identified as the most important driver for recent population changes in UK bats. The EU Habitats Directive, from which the UK legislation arose, obliged member states to establish a system of strict protection for bats and, as such, Statutory Nature Conservation Bodies (SNCBs) such as Natural England (NE) and Natural Resources Wales (NRW) administer the European Protected Species (EPS) licencing system. EPS licences legally facilitate the destruction or modification of bat roosts, but only where applications demonstrate that such activities will not be detrimental to the Favourable Conservation Status (FCS) of the species in question (Mitchell-Jones 2004). Natural England estimated they received approximately 4,430 such applications between 2015 and 2016, whilst Lintott and Mathews (2018) estimated that a minimum of 10,000 licensed and unlicensed bat mitigation cases take place in the UK each year.

## 1.2. Bearing Witness for Wildlife: Bat Roost Mitigation Project aims

The aim of this project was to use evidence-based methods to evaluate both the implementation and effectiveness of:

- New and modified bat roosting provisions, and

- Human-based processes associated with licensing and development.

The Esmée Fairbairn Foundation (EFF) awarded funding to BCT in 2017 to build on the existing evidence base by investigating the implementation and effectiveness of bat roost mitigation measures. More specifically, BCT's Bat Roost Mitigation Project focused on the modified or newly-installed roosting provisions provided as part of licensed bat mitigation work at development sites in England and Wales. The project also examined the human-based processes that drive the implementation of these measures. BCT used a mixture of desk-based and field survey techniques to study real-world examples of licensed bat mitigation work.

The study was therefore non-experimental and systematically gathered empirical survey data throughout the summers of 2017 and 2018. By closely evaluating the outcomes of mitigation schemes this was considered a unique opportunity to review some of the most prevalent conservation practices for bats, revealing what works and what doesn't at a practical level, and also the possibilities for adapting or reforming associated systems in the face of changing political and economic climates. The ultimate aim of the project was to use empirical evidence to inform future improvements or reform work in the ecological consultancy profession and support the production of updated bat mitigation guidelines.

*A glossary of Terms and Abbreviations can be found in Appendix 1*

# 2.0 Methods

## 2.1. Site selection

BCT used the following selection criteria to identify sites suitable for the project:

- Development projects where EPS licences were obtained for the damage or destruction of bat roosts (small domestic cases handled by volunteers or SNCBs, or those purely relating to disturbance, were not considered).
- Sites in England or Wales only.
- Sites where affected roosts were within built structures (i.e. buildings and bridges) instead of natural ones like trees, caves or rock faces.
- Sites where roosts of the following species were affected: common pipistrelle *Pipistrellus pipistrellus*, soprano pipistrelle *Pipistrellus pygmaeus*, brown long-eared bat *Plecotus auritus* and / or *Myotis* species (Natterer's bat *Myotis nattereri*, Daubenton's bat *Myotis daubentonii*, whiskered bat *Myotis mystacinus*, Brandt's bat *Myotis brandtii* and Bechstein's bat *Myotis bechsteinii*). This was because these species/groups are distributed throughout England and Wales and account for the majority of EPS bat licence applications. However, BCT did not discount sites where other bat species were present in addition to those listed.
- Sites where all roosting provisions and most construction activities were completed by the end of 2014. This allowed at least two years for bats to have started using new provisions before BCT's fieldwork in 2017. It was also required that EPS licences expired no earlier than 2006. This was two years after publication of the Bat Mitigation Guidelines (Mitchell-Jones 2004), meaning that most projects would have been informed by these guidelines.

## 2.2 Site sources and sample profile

To fulfil the aims of the project, BCT needed to obtain a sufficient volume of case study sites that not only met the above selection criteria, but also where EPS licence documents were readily available. Since there is no legal requirement for roost owners to provide access to third parties like BCT, it was not possible to use a completely random sampling strategy on the target population. Instead, the study used a self-selected sample by which roost owners willingly participated by inviting BCT staff to survey their property. However, since current data protection laws prevented BCT from contacting roost owners directly, case studies were obtained from two primary sources: 1) SNCBs; and 2) ecological consultants.

NE, NRW and ecological consultants were contacted to ask if they could identify sites meeting the criteria outlined in Section 2.1. and write to roost owners inviting them to take part in the study by contacting BCT. Contact was made with roost owners via email or in writing.

*More information on the process of acquiring sites and sampling can be found in Appendix 2*

Since it was not possible to randomly sample the total number of potentially available case studies, we cannot therefore extrapolate findings to represent bat mitigation schemes outside our sample. However, despite collecting data on numerous attributes to more fully understand the sample, BCT recorded no evidence to indicate our sample was *not* representative of comparable sites from the target population. All sites had been subjected to the EPS licensing process and 87% required some form of planning consent. Although both processes inevitably vary between sites, they are nonetheless formalised procedures which (in theory) should reduce the likelihood of notable outliers.

Nevertheless, it is important that the results in this report are taken in the context of the sample. In addition to the strict selection criteria described above, most sites were also smaller domestic sites requiring planning permission for minor developments, and almost all sites were situated in rural or semi-rural parts of lowland England and Wales. Since the sampling approach relied on a self-selection strategy by which roost owners willingly volunteered to take part in the study, this also inevitably restricted or eliminated certain schemes with higher-level security or health-and-safety issues such as MoD, National Rail or Highways Agency sites.

## 2.3. Field survey methodology

Procedures for both daytime and night-time surveys were based on current best practice guidance (Collins, 2016), although it was not possible to carry out repeat emergence/dawn surveys. All post-development monitoring surveys were completed between 23rd May and 5th September 2017 (Year 1), and 9th May to 23rd August 2018 (Year 2). Survey work was completed by Andrew Ross in both years (Class 2 licence for bat surveys in England and Wales), Kelly Rosier in Year 1 and Lorna Griffiths in Year 2 (Class 2 bat survey licence).

### 2.3.1. Daytime assessments

Surveyors completed daytime inspections for all buildings referred to in method statements. These included all buildings with retained / modified roosts or new compensation provisions. All proposed roost and access-point provisions were assessed against what had been proposed in the associated method statements. Where possible each provision was measured, described and photographed. Surveyors also recorded the presence of additional attributes which may have enhanced or reduced their ecological functionality such as noise disturbance, exposure to the elements, light levels, connectivity to vegetation and whether access points had subsequently been blocked after installation. A broad assessment of surrounding habitat was also made during the daytime.

Buildings and building-mounted bat boxes were thoroughly inspected to record bats or search for their evidence. Ladders, torches, video fibrescope, telescopic mirrors and binoculars were used as appropriate. Surveyors assessed loft voids internally where considered relevant to the assessment and where they could be accessed safely. Internal void dimensions, and characteristics were fully recorded. Internal void temperatures were taken using a hand-held thermometer and compared to external ambient temperature readings taken shortly before or after. Bats or any evidence of recent occupation was recorded and droppings collected for later DNA analysis.

Although tree-mounted bat boxes were surveyed in a similar manner, natural tree-crevices were not formally inspected since this was beyond the scope of this project. When bat boxes were installed too high for ladder inspection, they were prioritised for night-time dusk or dawn surveys to establish bat occupancy. It was noted early on that certain structural details for bat box models were frequently not readily available through supplier websites. Therefore, the dimensions of internal roosting spaces and access points were measured *in-situ* wherever possible in addition to their make and model. Where the height of the boxes prevented surveyors from taking these measurements, measurement details were obtained from Wildcare Ecology Supplies.

Several sites had installed roost enhancement provisions either as additional measures in the EPS licence or as separate requirements for planning. Although distinguished from each other during the data-entry stage, enhancement provisions were surveyed using exactly the same procedure because they could also provide valuable information about the effectiveness of new provisions.

DNA analysis of 77 bat dropping samples was completed by Swift Ecology in partnership with Ecotype Genetics Limited. This was prioritised for ambiguous droppings present inside roost structures or access points and where bats were either absent at the time or a reliable sonogram from emergence surveys was not available. Droppings suspected to belong to *Myotis* spp were also prioritised because of the general lack of information regarding their roost requirements and unreliability of accurately distinguishing between species using visual dropping identification and sonogram analysis. Small *Pipistrellus* spp. type droppings were also analysed in the interest of furthering our understanding of how *P. pipistrellus* roosting requirements may differ from *P. pygmaeus*. Furthermore, separating droppings of this genus from those of small *Myotis* species droppings like whiskered bat *Myotis mystacinus* is often unreliable. Droppings typically characteristic of lesser horseshoe *Rhinolophus hipposideros* were excluded from DNA analysis.

### 2.3.2. Night-time surveys

With the exception of two sites where compensation provisions were fully inspected during daytime inspections, all sites were subjected to at least one dusk emergence or dawn re-entry survey. Vantage points for two BCT surveyors were scoped during the daytime with the aim of covering the maximum number of access points and external roost provisions with good lines of sight. BCT surveyors were equipped with ultrasonic bat detectors / recorders for later analysis. Since the Peersonic bat detectors used on surveys were triggered automatically by bat passes, surveyors prioritised their attention on whether bats emerged or re-entered roost structures rather than documenting general bat activity. However, any notable flight-paths, possible off-site roosts or noteworthy species were recorded. Staff recorded the time, bat species (where possible) and behaviour of all bats emerging or re-entering structures. WAV sonogram recordings were analysed manually using Bat Sound 4.2 with reference to Russ (2012) where appropriate. Surveyors also recorded the presence of any artificial lighting during night-time surveys.

Sites were often too large or complex for coverage by two surveyors during a single dusk survey. Therefore, a dawn re-entry survey was also completed (using different vantage points) in these instances to improve coverage. Dawn surveys were also occasionally performed from the same vantage points to add accuracy to the previous night's emergence record where the presence or number of roosting bats was ambiguous. Where surveyors could not sufficiently cover an adequate proportion of provisions using a single dusk and / or dawn survey, they completed a follow-up night-time survey(s) at a later date. Such follow-up visits were also completed where the previous survey effort was constrained by poor weather conditions or access availability.

Bat abundance levels were used for comparing bat counts and were taken as the maximum number of bats recorded. For making before-and-after comparisons, baseline results where numerous surveys took place were generally combined so the abundance level was simply the maximum number recorded on a single occasion. Where only bat droppings were recorded, this was taken as a single bat to facilitate quantitative analysis. Note that surveyors occasionally recorded bat droppings in relatively high densities and the presence of other signs (e.g. oil marking on wood) may have indicated a maternity roost or higher bat abundance counts at other times of the year. Although such observations were always documented, dropping densities were not used to infer bat abundance as this would have introduced unacceptable subjectivity. The results should be read in this context.

### 2.3.2. Roost owner interviews

Where possible, BCT endeavoured to complete informal interviews with roost owners in person to gather information about their attitudes and opinions regarding key elements of the planning and EPS licensing process, their experience working with ecologists and bats in general. Such interviews were predominantly intended for individuals involved in the original EPS licence work or those who had responded favourably to BCT's request for survey and were therefore living or working in the same location as the roosting provisions. Such interviews were not always feasible or considered appropriate for certain sites where BCT had not liaised directly with such individuals, therefore they were completed at 44 sites. The following questions were asked:

1. Why did they respond positively to BCT's request to take part in the project?
2. How aware were they about whether bats used any of the roosting provisions?
3. What was their original attitude towards bats and bat conservation before the development process?
4. Did their attitude change during the development work? If so, how?
5. What were the most positive parts of the experience?
6. What were the most negative?
7. To what degree did they discuss bat conservation with their ecological consultant? If so, what aspects were discussed?

### 2.3.3. Equipment

The following equipment was used throughout the fieldwork for this study:

- Peersonic RPA2 bat detectors: Full-spectrum ultrasonic recorder of WAV files up to 192kHz
- Telescopic 3.2m ladder for internal access into loft voids (classified to BS EN131 for trade use)
- 3-stage 5.69m ladder (classified to BS EN131 for trade use)
- RIDGID SeeSnakeMicro CA-25 inspection camera
- Telescopic mirrors
- Close-focus binoculars
- LCD head and hand-held torches
- Digital camera
- High powered 7000 Lumen LED torch
- Tape measure
- Laser distance measurer
- Clear plastic 18mm x 65mm test tubes for bat dropping collection
- 2-way radios for real-time contact during emergence surveys
- Thermometer

The Peersonic RPA bat detector was selected because it was one of the more affordable units for recording echolocation calls in full-spectrum at the start of Year 1. Although used as the primary recording device, surveyors also used it in combination with secondary hand-held detectors to aid live detection and identification in the field such as the EM3 by Wildlife Acoustics and Magenta 5 heterodyne detector.

Although project resources prevented the use of more advanced field equipment such as infrared and thermal imaging cameras, such equipment had rarely been employed by case studies during original baseline assessments. Therefore, the use of more traditional approaches to roost detection and colony counts more accurately reflected the techniques typically employed during the original assessments. Furthermore, this project did not make use of long-term temperature loggers because of the very large number of roosting provisions surveyed.

In terms of computer software, all WAV sonogram recordings were analysed using Bat Sound 4.2. Statistical analysis was completed using GenStat 19.1 for Windows by VSNI.

### 2.3.4. Survey Limitations

Surveyor coverage: Sometimes it was not possible for field staff to obtain 100% coverage of mitigation provisions during night-time surveys, even with multiple site visits. For the rare occasions where surveyors could not reasonably establish bat occupancy using daytime or night-time survey techniques, this constraint was recorded so that such provisions could be excluded from certain assessments during data analysis.

Weather conditions: Surveyors aimed to complete all night-time surveys during weather conditions that were close to optimal, with sunset temperatures at 10°C or above and no rain or strong wind (Collins 2016). Local weather forecasts were always monitored prior to surveys and the above variables recorded at the beginning and end of each survey. On the rare occasions where surveyors considered local weather conditions to be acting as a potential constraint, follow-up survey visits were always scheduled during more optimal conditions.

Bat identification: Records for species-level identification were restricted to cases confirmed by DNA analysis of droppings, confident identification of live bats or non-ambiguous echolocation calls. However, records were occasionally reduced to the genus level or 'bat' where the available field data prevented confident species identification. This included situations where surveyors could not collect a sufficient number of droppings to facilitate DNA analysis, live bats could not be examined *in-situ* or echolocation calls were absent or ambiguous.

Roost information: Every effort was made to record structural information from modified roosts, newly-installed provisions and newly-identified non-intended roosts. However, it was frequently not possible to obtain such information about roosts without damaging the structure of the roost or host building. Such information may have included internal dimensions or the presence of certain materials. In these instances, surveyors recorded as much information as possible about the access point and any details that could be observed beyond it. Any missing details regarding new provisions were recorded as being constrained so these attributes could be excluded from certain aspects of data analysis.

# 3.0 Implementation of bat provision by type

For the most part this section is reporting on the implementation of totally new provisions due to difficulties isolating entirely new features in modified and retained roosts and also the difficulties separating compensatory features from those installed for enhancement in modified and retained roosts.

## 3.1. Background

Several studies have examined the implementation of ecological mitigation schemes alongside effectiveness. Briggs (2004) observed that several case studies had not followed proposed mitigation designs, while Waring's (2011) study reported that 65% of bat mitigation projects had not complied with ecology-related planning conditions.

Some of the more frequent issues identified in bat mitigation schemes have been inappropriate positioning of bat boxes (Mackintosh 2016), damaged or missing bat boxes (Aughney 2008) and insufficient consideration and specifications for artificial lighting (Waring 2011) (see Section 4.4.5). Likewise, possible barriers and solutions to these issues have related to poor communication between developers and consultants (Mackintosh, 2016), the lack of compliance inspections (Waring 2011), SNCB budget cuts (Kerslake 2019) and a lack of detail in method statements (Waring 2011) (see Section 6).

As part of field assessments for this project, we collected data relating to how installed mitigation provisions compared to those originally described in method statements. This section therefore examines the implementation of new provisions for bat mitigation schemes, reporting on the following project aims:

- To evaluate implementation rates for newly-installed provisions by comparing details of proposed measures to those applied.
- To investigate the underlying drivers behind implementation rates by examining the possible effects of other factors including site safeguards and roost-owner attitudes.

## 3.2. Methods

The following data was retrieved from method statements:

- The number and location of proposed new roosting provisions.
- Structural descriptions relating to size, material and design.
- Proposals for internal environmental conditions such as temperature, air flow, light-levels and protection from wind / rain.
- Proposed measures for managing levels of human disturbance such as proximity to artificial lighting, presence of services and access restrictions.
- The number, location and design features of access points.

All measures were ground truthed by comparing method statement proposals to those applied in the field. This was facilitated by transcribing all associated details into standardised 'tick-sheets', listing and describing each provision separately. Although some features were recorded as 'absent' in the field during BCT surveys, this was because it was occasionally not possible to find them on large buildings or very large areas of woodland, particularly if the location of new provisions was not precisely described. Such provisions were classified as 'unknown' whenever there was uncertainty and therefore excluded from the assessment.

Implementation rates for sites and individual provisions were classified as follows:

- Absence-rates: The proportion of absent provisions relative to those proposed.
- Deviation-rates: Provisions installed differently compared to method statement descriptions.
- Precision-rates: Provisions precisely consistent with method statement descriptions.
- Installation rate: The sum total of provisions installed, including those deviating from method statement description.

- Enhancements: These were categorised separately and represented provisions not mentioned in method statements. It was unclear whether these were installed as substitutions for absent provisions, whether they would have been installed anyway or whether they were installed as part of separate planning elements.
- Damaged: Provisions originally installed but later removed or rendered functionally obsolete during the operation phase.

If provisions displayed deviations or were damaged, then the reasons for being categorised as such were also recorded where they were known. It is acknowledged that some deviations would have been intentional and the reasons were generally unknown unless the process had been documented in letters to SNCBs or were drawn to our attention by the ecologist or roost owner.

Although 13% of method statements proposed that roost provisions would be 'seeded' with bat droppings, BCT could not accurately assess such proposals because: 1) it was likely that droppings would have degraded over the long time-frame between roost construction and our assessment; 2) the feasibility of distinguishing between the seeded droppings with those of roosting bats; and 3) some roosts were in locations that could not be inspected internally.

## 3.3. Results

### 3.3.1. Overall implementation rates

BCT assessed the implementation of 2,333 newly proposed roost and access point provisions during the project. Figure 3.1 displays the gross implementation rates for these provisions across all sites. When considered together, 61% were installed precisely as specified while 19% deviated in some way from that proposed. Absent provisions accounted for 11% of the sample and enhancements 8%.

Despite being installed during construction, approximately 1% of provisions were later removed or rendered functionally obsolete during the operation phase. These were described as damaged because some form of remedial action was required before they could adequately function as a roost or access point provision. Wall or tree-mounted bat boxes accounted for 50% (n = 22) of these, most frequently due to being dislodged by flooding, lightning or wind. Other causes included general degradation over time and defects with heated bat boxes. The remaining structures were predominantly access points (45%, n = 22) that had been blocked by bird mesh, grating, draught excluders, over-hanging roof lining or overgrown moss.

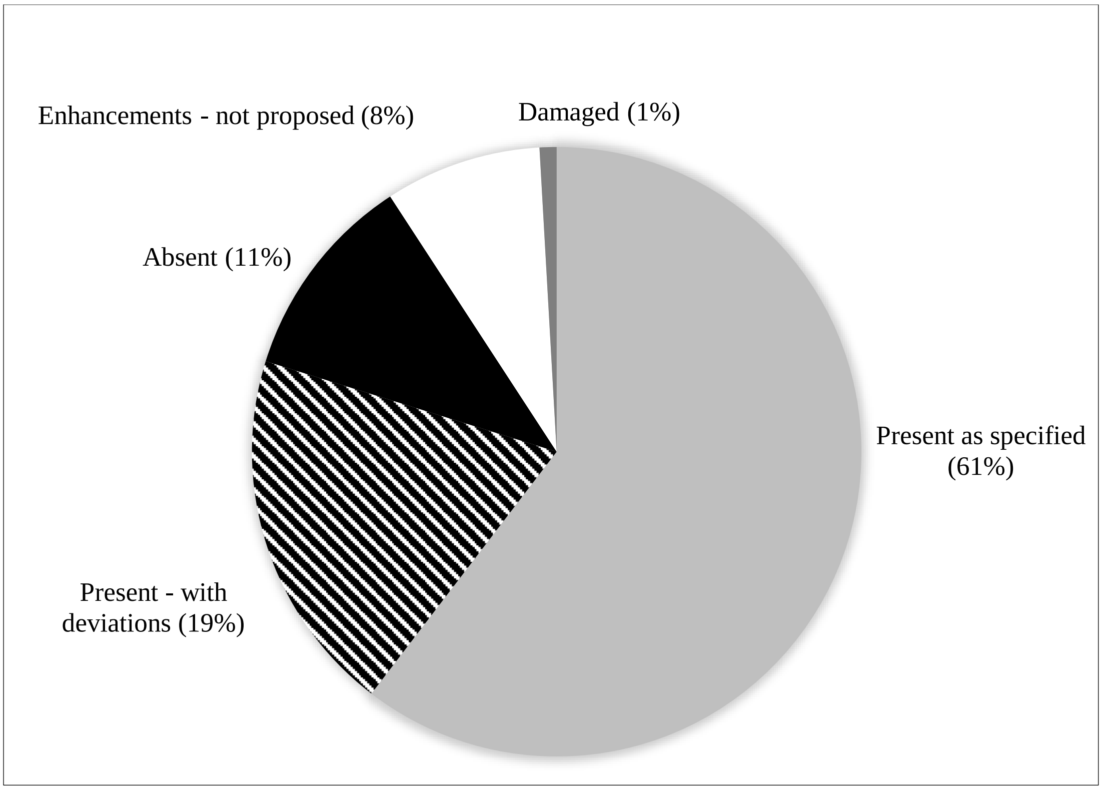



**Figure 3.1**

*Overall implementation rates for installed provisions*

### 3.3.2. Inter-site variability

Implementation rates were examined separately for each site to understand the magnitude of inter-site variability (Figure 3.2). The average rate for precisely-installed provisions was 56% (n = 71). This was noticeably higher compared to absent provisions (15%) or those installed with deviations (23%). Although precision-rates varied across sites, histograms showing average absence and deviation-rates (Figures 3.3 and 3.4) were both positively skewed to the left. This indicated that sites with frequent instances of different or absent provisions were less abundant than sites where this occurred occasionally.

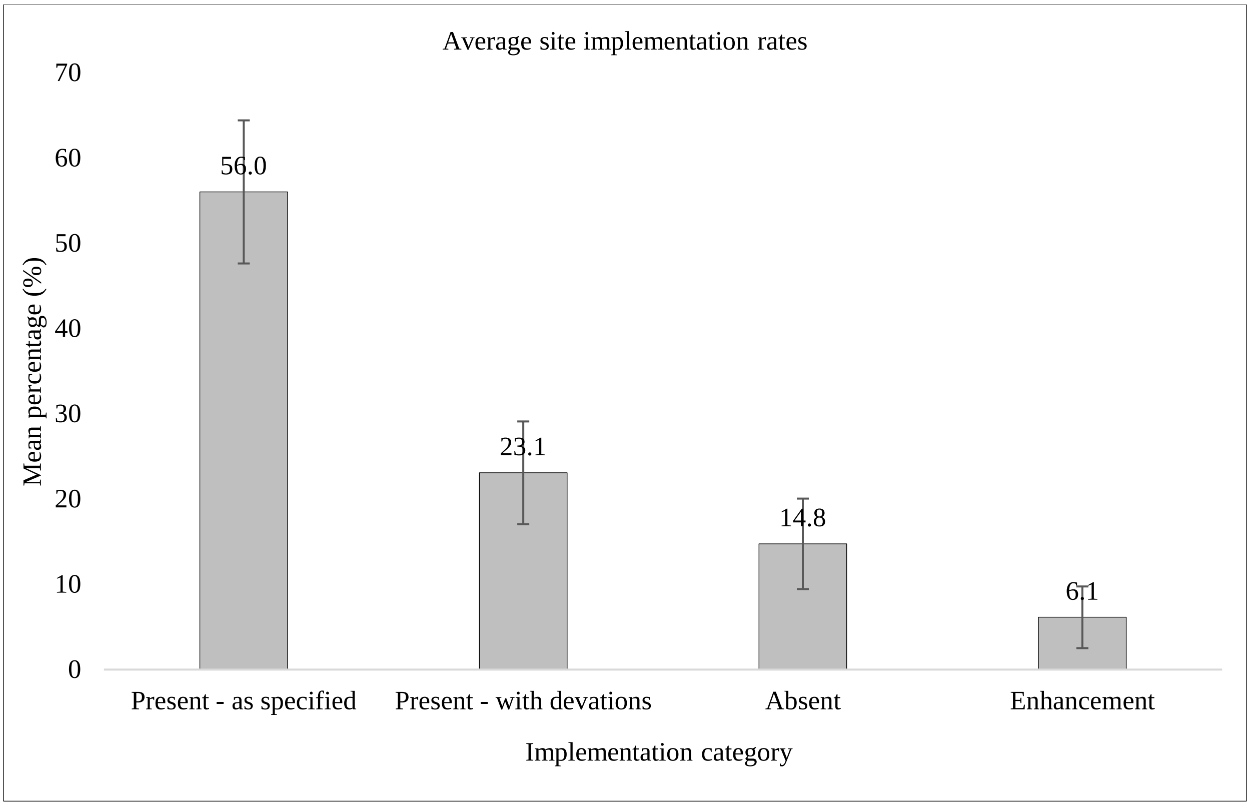



**Figure 3.2**

*Average site implementation rates*

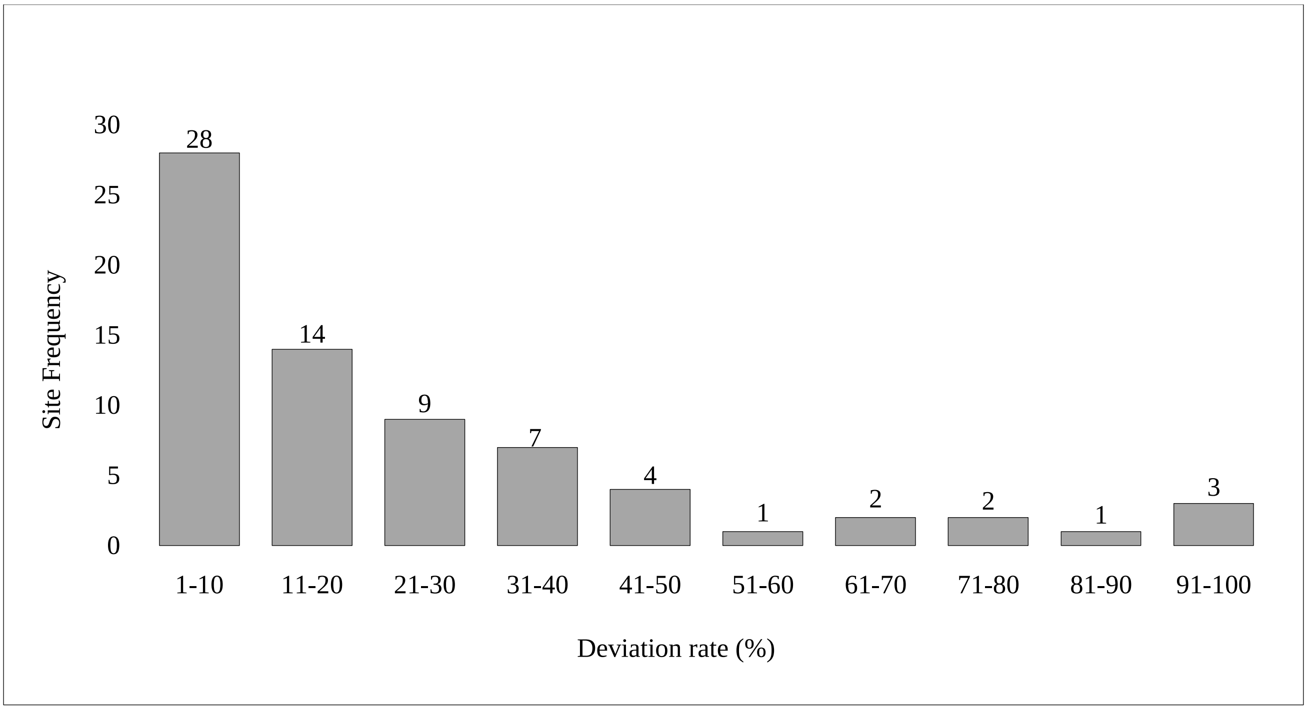



**Figure 3.3**

*Histogram showing deviation-rate variability across sites*

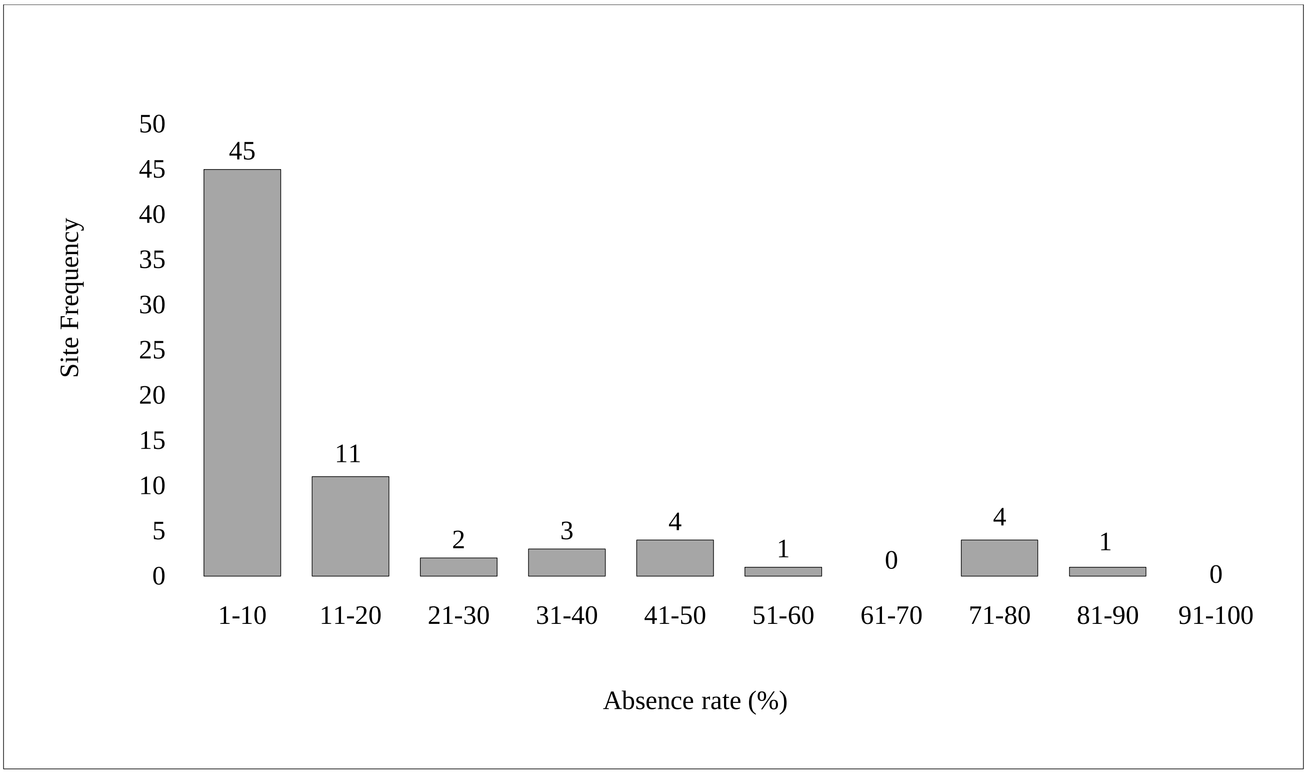



**Figure 3.4**

*Histogram showing absence-rate variability across sites*

### 3.3.3. Differences between provision types

Implementation rates for different roost and access point provisions were compared (Figure 3.5). Although 80% of all provisions were installed to some degree, the deviation-rate for roost provisions (28%, n = 806) was higher compared to access points (15%, n = 1,527). This was to be expected since roost structures are more structurally complex than access points and therefore have more scope for changes during installation. Absence-rate differences between roosts and access points were less pronounced (13% and 10% respectively).

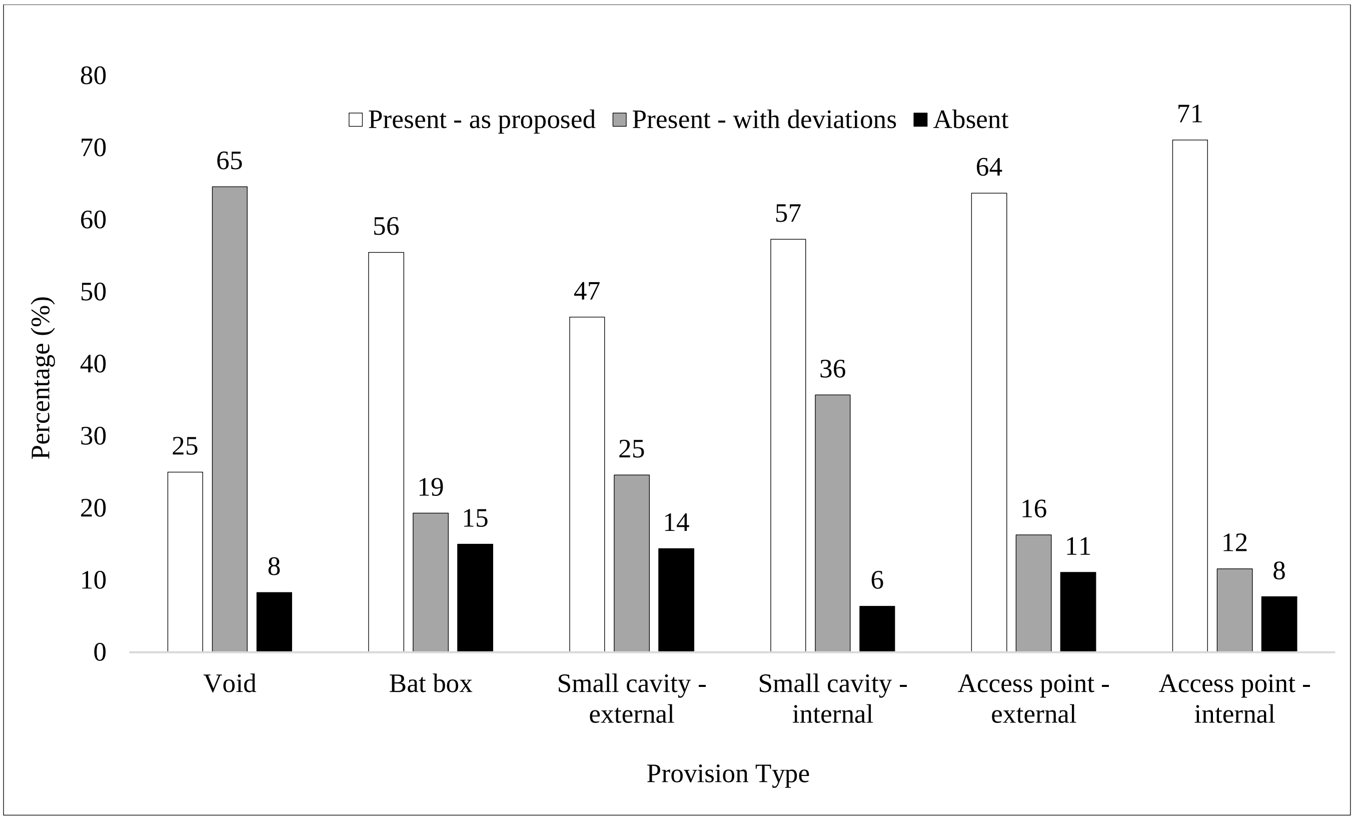



**Figure 3.5**

*Bar chart showing average implementation rates for different types of provision (not including damaged provisions or enhancements)*

Voids featured both the highest overall installation-rate (90%, n=48) and highest deviation-rate (65%). New bat lofts in particular had a noticeably high deviation rate of 73% (n = 33) followed by wall stonework cavities (46%, n = 26) and ridge voids (38%, n = 15). Bat boxes, external access points and internal access points generally had the lowest deviation-rates of 19%, 16% and 12% respectively. Internal bat boxes were the most precisely installed provision type (78%, n = 32) and had an absence-rate of 0%. Again, these observations were attributed to voids generally being the most structurally complex type of provision, while bat boxes and access points are simpler structures with less scope for deviations.

Despite their low deviation rates, bat boxes and small external cavities had the highest absence-rates of 15% (n = 254) and 14% (n = 333). In particular, 35% of externally wall-mounted bat boxes (n = 87) and 26% of wall top crevices (n = 78) were absent. Bat tiles were the most frequently absent access point type (46%, n = 56).

### 3.3.4. Types of deviation and deviation-rates

We examined in detail provisions with the highest deviation-rates and looked at what was installed differently to that which was proposed. With respect to new bat lofts, differences in internal size and volume were the most frequent deviations. Indeed, 100% of bat lofts with deviations (n = 24) had minor differences (< 1 m) in height, width or length. Although 42% of deviating bat lofts had more pronounced differences in width and length (> 1 m), only a single void (i.e. 4%), deviated > 1 m in height. Other frequent deviations included fewer external access points (27%), loft hatch signs being absent (27%) and bitumen roofing felt and / or sarking being absent or reduced (23%). Additional deviations included fewer (or absent) internal cavities (19%), loft hatches being too large to dissuade storage (12%), ineffective sound-proofing and the absence of internal baffles or perching spots.

Use of alternative bat box models was the most frequent cause of bat box deviation-rates (35%, n = 66). This was followed by wall-integrated designs being hung or mounted instead of integrated into wall elevations (26%). Additional deviations included different aspects (11%), slightly different positioning (14%) and boxes intended to be wall-mounted being hung on trees (6%).

The causes behind small external cavity deviation-rates (excluding bat boxes) were more variable (n = 66). However, the most frequent causes were the complete absence of access points into the structure (26%), fewer access points being installed (14%), or internal volumes being noticeably larger (18%). Height, aspect, broad positioning and materials were always as proposed.

Most access point deviations were simply caused by the installation of alternative structure-types (24%, n = 229). For example, a gap at the gable apex being replaced by a larger hole lower down in the gable wall. The next most frequent cause was access point apertures being wider than proposed (23%). Additional reasons included more minor deviations in design detail (14%). For example, projecting access points being angled horizontally instead of downwards, the absence of crawling platforms on the inside of tile entrances into loft voids, or ridge access points being cut into tiles instead of mortar. Approximately 11% of deviating access points used different materials, such as brick or slate entrances and landing platforms being replaced with lead. Apertures were installed longer than proposed in 11% of deviating access points.

### 3.3.5. The influence of site, consultancy and provision-type

We examined the degree to which site implementation rates may be caused by site-specific factors, the ecological consultancies overseeing bat mitigation work or the type of new provisions. These factors were formally analysed using a binomial GLMM mixed model with site, ecological consultancy and new provision types as random terms.

Site implementation rates did not differ between ecological consultancies. When fitted to the model as a fixed term, differences between consultancies were highly non-significant (chi-squared = 12.29 with 27 d.f., p = 0.993). In contrast, when provision-types were removed as a random term, inter-site variability was significant (chi-squared = 103.61 with 68 d.f., p = 0.004**). However, when new provision types were fitted into the model then inter-site variability was not significant (chi-squared = 86.24 with 68 d.f., p = 0.067) despite differences between provision types being highly significant (chi-squared = 38.66 with 11 d.f., P < 0.001***). Results therefore suggested that site-specific factors such as the mitigation strategy, baseline conditions or other third-party contracting staff had a significantly greater influence over implementation rate variability than the ecological personnel delivering the work. We did not collect any data on the influence of contractors on implementation rates so this cannot be assessed. The model also indicated that the type of provisions used in the mitigation strategy may have a more significant effect than other site-level factors, possibly due to their different complexities as discussed above.

### 3.3.6. Safeguards for new provision installation

Method statements for 10% of sites were embedded with formalised assurances that roost provisions would be installed as specified. These generally specified that such provisions were already installed, that named individuals would accept responsibility for funding them or that named ecologists would complete compliance monitoring. Planning conditions for 6% of cases also specified that photographic proof of such measures was provided to LPAs. Overall, 50% (n = 10) of these cases technically featured absent provisions, with absence rates ranging from 5% to 40%. However, the mean absence rate for these sites was 11% - slightly less than the overall gross rate of 14%. (See Section 6)

### 3.3.7. Deviation overview

The six case studies with the highest absence-rates (>59%) were examined in detail. However, there were few similarities between them in terms of possible underlying causes. Each scheme had been managed by separate ecological consultancies, four of which were responsible for managing the ecology at other sites in our sample with noticeably higher implementation rates. It was noted that the principal contractor at one site went into liquidation before completing the development meaning that some provisions were simply not finished. Another scheme did not install several key provisions because much of the original host structure was able to be retained and alternative modification measures were therefore used instead. This is likely to have occurred because impacts were either unknown or not fully specified at the baseline stage, or the scope-of-work changed after the EPS licence was issued. At another site the roost owner did not appoint ecological support during construction after the original ecologist withdrew earlier in the project. Other sites involved numerous roosting provisions being absent for unknown or undocumented reasons

## 3.4. Discussion

The fact that 80% of new provisions were installed to some degree and only 11% were absent is perhaps reassuring. Such rates were noticeably higher compared to those for monitoring programs where only 38% were fully completed and 33% cancelled altogether (Section 7). When comparing implementation to effectiveness, average occupancy rates for new roosting provisions were 18% (Section 4) and therefore considerably lower than corresponding implementation rates. Therefore, if taken at face value, one may conclude that provision effectiveness may be a more limiting factor to bat conservation outcomes than implementation of that provision. However, such broad statistics do not necessarily reflect the various site-specific or species-specific scenarios, so it is important they are not taken out of context.

There was no relationship with the ecological consultancies or practitioners employed to oversee such work, many managing different schemes in our sample with a range of implementation rates. This lack of variability suggests that even projects overseen by highly experienced bat workers are not necessarily beyond unintended and unfavourable deviations from method statements. It is therefore important that all ecologists named on EPS licences recognise that such occurrences can happen to anyone if they are not adequately accounted for.

It is the responsibility of licence holder(s) to ensure new provisions are installed as prescribed. Although 48% of case studies featured signed, formalised statements embedded into method statements that these prescriptions would be followed, only a small proportion included planning conditions or specific assurances relating to installation. However, since installing the new provisions is a standard requirement of the EPS licence anyway, it could be argued that such safeguards simply replicate the act of signing the licence application. Nevertheless, there was no evidence to indicate that such safeguards made any tangible improvements to implementation rates in our sample.

Although implementation rates displayed considerable variability between sites, we found no relationship with scheme complexity in terms of the total number of proposed provisions. A far more influential factor was the *type* of new provisions being installed. For example, absence-rates for new loft voids were noticeably lower compared to bat boxes, access points and other external cavity provisions. In terms of deviation-rates, more structurally complex provisions like loft voids and certain small cavity roosts were more likely to be installed differently compared to simpler structures like access points and bat boxes.

Gross implementation rates also do not reveal the potential magnitude of certain effects. After all, only 1% of provisions were assessed as damaged and these mostly related to bat box models where bat counts never exceeded six bats in our sample. However, two roost provisions were assessed as damaged because their access points had been blocked, potentially excluding maternity colonies. BCT informed the ecological consultants and / or named ecologists so they could ensure remediation (it would not be in the public interest to report these cases to the police bearing in mind that the site owners were cooperative and too much time had elapsed since the access points were blocked for a prosecution case to be taken forwards). Therefore, despite accounting for a very small proportion of provisions as a whole, such effects may be significant. In contrast to the ‘Acts of God’ generally responsible for damaged bat boxes, these were failures of post-development processes to adequately safeguard roosts.

### 3.4.1. Implications for bats

It is likely that broadly assessing implementation using measures of bat presence or abundance at the site level would not detect the effect that individual absences and deviations may have on bats.

Absent provisions, by definition, cannot be effective because they are not available to bats. Furthermore, results for this project indicate that certain provision types are more significantly associated with higher rates of effectiveness (Section 4) and implementation than others. Therefore, by individually assessing provisions and their implementation at the roost-level, it is possible to make reasonably logical and evidence-based assumptions about the potential effects on bats. For example, if certain provision types are absent on site then we can attempt to understand the effect by comparing them to those that are present. Likewise, we can use observed outcomes from precisely-installed provisions to make comparisons to those that were installed differently.

For example, implementation rates for consistently ineffective provisions may not make a significant difference to bat conservation outcomes at the site-level. However, wall top crevices were one of the most frequently absent provisions (26% n = 78) despite being one of the most consistently effective for roosting *Pipistrellus* spp (Section 5). Therefore, despite accounting for a relatively low proportion of absent provisions overall, such occurrences may have genuinely compromised mitigation endeavours at these sites.

The true effect of deviation-rates is also likely to be highly specific to the provision-type and nature of the deviation. Although the decision-making process was usually unknown, it is possible that some deviations in our sample may have been approved by on-site ecologists to improve measures beyond what was proposed in method statements. Likewise, certain unintended deviations may also have unanticipated but positive outcomes. However, it is also feasible that deviations were not intended or went unnoticed until final sign-off visits or were overlooked entirely.

Other deviations may have relatively low levels of importance. For example, this project did not detect any noticeable association between occupancy rates and bat box height or aspect (Section 4). Therefore, minor deviations in bat box positioning may not have significantly affected their effectiveness in our sample. The influence of other deviations may be more ambiguous. For example, our implementation data demonstrated that internal height deviations in bat lofts were less frequent and less pronounced compared to width and length. Yet width and length may be less important to a loft's overall effectiveness compared to height despite having a more conspicuous effect on overall volume.

However, certain deviations will inevitably reduce effectiveness and we recorded some evidence to support this. For example, bat occupancy rates for new stonework cavities were significantly lower compared to other provisions (Section 4). This was particularly noticeable because this was one of the most frequent naturally-occurring baseline roost types. In terms of implementation, deviation rates for wall stonework cavities were also noticeably higher (46%, n=26) than other small cavity roosts, mostly due to larger access points and internal volumes. Although we cannot directly attribute such reduced effectiveness to high deviation-rates, such a cause-and-effect relationship is nonetheless a logical possibility. Similarly, our assessment on access point effectiveness in Section 4 demonstrates that extremely subtle alterations in aperture width (+/- 5 mm) may positively or negatively affect bat occupancy rates. Our implementation data demonstrated that 23% of access points were installed wider than proposed. Such deviations may therefore be extremely subtle and easy to overlook or disregard during sign-off visits. However, such details could feasibly have a cumulative effect by consistently undermining effectiveness when such deviations are repeated over hundreds of different mitigation schemes over many years. It is therefore important that appropriate precautions, such as some level of site supervision and mid-development compliance inspections, are carried out to minimise the extent of such deviations. This is particularly the case for permanent measures integrated into buildings which have a limited potential for retrospective changes if not identified until final sign-off visits.

### 3.4.2. Implications for stakeholders

Alongside potential implications for bats, improved implementation rates are equally likely to benefit stakeholders, particularly in the short-term. Although it is possible that ecological consultants may have approved certain design modifications when presented with new information in the field, it is important that such adaptations are agreed with SNCBs and documented because if we intend to use post-development monitoring as an evaluation tool (Section 7) then not doing so compromises our ability to learn from effective provisions and replicate success.

Perhaps the most notable disadvantage of unintended absences and deviations would be the possible financial implications and damages to professional-client relationships (and reputations) if changes need to be made retrospectively. The fact that so few case studies proposed and implemented such remedial measures may demonstrate the limited options available for such work. Unlike other areas of ecological mitigation such as habitat management, new roost provisions are usually designed to be permanent structures. Mounted-bat boxes aside, such structures therefore have a more limited scope for adaptive management after their completion. Although the cost of such measures can be significant, contingency fees for such actions are unlikely to be built into most project budgets. It may therefore be ambiguous whether financial liability rests with contractors, the developer, client / licence-holder or the ecologist. Such retrospective modifications can therefore place individuals or companies in extremely difficult positions and impair professional working relationships at a key point in mitigation projects. Such scenarios also have the potential to jeopardize bat conservation attitudes held by certain stakeholders.

### 3.4.3. Barriers and opportunities for improving implementation

We have identified that the type of provisions used in the mitigation strategy have a more significant effect on implementation than other site-specific factors (probably relating to the complexity of the provisions). Also that site-specific factors are likely to be more important than the individual consultants working on the case, because our study included examples of both good and poor implementation in cases involving the same consultant. However, our sample is unlikely to be representative of all consultants.

Communication (both verbal and written) amongst members of a development project team are also likely to play a part. One issue identified in this project involved the format of license application documents. Although it is acknowledged that SNCB templates have been updated since 2014 (the cut-off date for our case studies), the documents examined in this study were presumably designed to enable licensing authorities to assess proposals systematically and efficiently. Ensuring that such method statements are interpreted accurately by contractors is a key role for appointed ecologists. However, it was noted that certain provisions may have been referenced slightly differently in different parts of method statement text, or may not have been fully described or numbered. Provision descriptions were sometimes spread throughout multiple sections of documents or cross-referenced with planning reports that may not have been available. There were also discrepancies between the method statement text and attached figures, frequently including key details in small-print not repeated elsewhere.

Although this kind of long-form report is an invaluable reference text, it may not lend itself to being a practical means of informing on-site contractors during the construction phase, or indeed ecologists during compliance checks and sign-off visits. Ultimately, if extracting specific mitigation details from method statements is excessively laborious and time-consuming then it is more likely that key details could be overlooked.

In the past, drawings of how to construct bat roosts, entrance points and other features was available from English Nature (undated, found here: https://www.lakedistrict.gov.uk/planning/planning_how_to_apply/planningguides/batroosts) but as far as we are aware these have not been updated more recently. Drawings of features suitable for bat access and roosting are available in Designing for Biodiversity: A technical guide for new and existing buildings by RIBA and BCT (Murphy *et al* 2013) but it is not clear how much this is used bearing in mind the drawings appear in a hard copy of the document but are not readily available elsewhere (BCT are currently looking to update this). Clearly if drawings are provided to the development project team, rather than text descriptions, there is a higher likelihood that features will be installed correctly.

Although beyond the remit of this project to prescribe any single method for mitigation projects, we would suggest that extracting key information to a more streamlined reference document would be a more efficient and effective way for relaying mitigation details in the field. For example, BCT surveyors used standardised 'tick-sheets' for assessing provisions in the field, listing and describing each access point(s) and roost according to their host building with relevant figures. It is recommended also for consultants to talk through architectural drawings and other plans/diagrams rather than relying specifically on what is written for SNCB licensing purposes.

However, even if the proposals are well communicated in documents there is no certainty that they will end up in the hands of the construction team and it would seem appropriate to require a higher level of contact between ecologists, architects and contractors, for example through site visits during construction as features are actually installed.

Since virtually all method statements proposed explicit measures for minimising the risk of killing or injury to bats, it was surprising that so few described measures for ensuring new provisions were appropriately installed. Our analysis identified no link between site implementation rates and measures such as mid-development compliance checks or direct supervision. There could be several reasons why such a link was not clear in our results: 1) compliance visits may not have been completed; 2) building contractors may have misunderstood or ignored ecological instructions during compliance visits; and 3) compliance visits may not have been performed effectively.

Regarding the first point, it is feasible that ecologists recommended mid-development supervision and compliance visits as part of the licensing process but developments proceeded without their input. Alternatively, there may be a genuine and well-intentioned reluctance for ecologists to increase project costs for their clients by recommending such measures. The likelihood of either scenario may increase if client-ecologist relationships have become strained over time or clients perceive that such measures are unnecessary. Of course, with ecology being a highly competitive profession, such measures are only feasible if they become standard practice and widely adopted throughout the profession.

The above notwithstanding, compliance checks may not always be the most appropriate or pragmatic solution for addressing all implementation issues. These will generally be highly situation-specific. However, considering the potential negative repercussions if unfavourable deviations do occur, it would be advisable for ecologists not to simply presume that all measures will be installed correctly without any direct involvement. It is therefore in their interest to find solutions for safeguarding themselves and their mitigation project from such outcomes.

Although implementation rates varied across sites and are likely to be driven by a diverse range of site-specific causes, the nature of such deviations were highly provision-specific. For example, bat tile access points were far more likely to be absent than bat houses or bat lofts. Likewise, most bat loft deviations throughout our sample were usually attributed to the same factors, such as differences in width / length and absence of signage on loft hatches. This makes it feasible to pre-empt such deviations ahead of time. This also enables ecologists to draw attention to possible deviations to contractors. Such information may also help ecologists and developers schedule any necessary compliance visits. Documenting and submitting such information with licence return forms could be a valuable resource whereby lessons learned from past-projects can be reviewed and shared for advising bat workers at future projects. Even if not adopted in this way, individual consultancies may benefit from project debrief sessions in the interest of highlighting such 'red-flags'.

Initiatives such as the Earned Recognition project between NE, the Chartered Institute for Ecology and Environmental Management (CIEEM) and BCT (Red Tape Initiative, 2018) have the potential to raise standards in areas of the profession such as bat mitigation implementation. As discussed above, there are numerous advantages to improving implementation for both bats and stakeholders. However, it is also important that such expectations are not unrealistic. For example, BCT's own data concerning implementation rates demonstrated that only 13% of case studies precisely implemented *all* roost and access point provisions. Therefore, although there is no doubt plenty of scope for improvements, baseline standards also need to be sufficiently pragmatic by accounting for certain factors. There should be reasonable scope for experienced named ecologists to approve certain minor design or location modifications / improvements when presented with new information during construction. For example, one case study in our sample was required to change the location of a wall-mounted bat box because it would have been directly adjacent an active bees' nest, while the location of a provision at another site needed to be changed because a chimney flue prevented it from being installed.

It must also be remembered that all professional bat workers learn a significant part of their trade 'on-the-job' to some extent, continuously being exposed to new scenarios throughout their career but particularly in the early stages. Learning from certain errors in judgement or occasional oversights during implementation are an important and inevitable part of professional development and distinct from individuals consistently displaying negligence, acting unethically or repeatedly exposing themselves to situations beyond their realm of experience. Reduced site implementation rates may also be caused by unforeseen circumstances that could not reasonably have been avoided, such as third-party interventions and individuals working beyond or against their agreed remit.

The data collected during this project does not allow an assessment of the influence of contractors on implementation rate. Further studies could perhaps collect such data in order to further our understanding of this and respond with awareness raising, training or the introduction of specific accreditation schemes as appropriate.

## 3.5. Recommendations

- Resources should be produced and made readily available (e.g. downloadable pdfs online) showing how bat access and roosting features can be constructed. These would provide a valuable resource for mitigation design and allow consultants to better communicate intentions to other members of a development project team.
- Site supervision by an ecologist during the installation of all bat roost mitigation features (but in particular those features which showed high deviation or absence rates or those that are particularly difficult to alter retrospectively) should be considered a *standard approach* to ensure those features are installed correctly from the start, avoiding the difficulties associated with retrospective changes to built structures. Any deviation from this approach should be fully justified in the licence application.
- Standards should continue to be raised among ecological consultants – in particular verbal and written communication and clarity around financial and practical liability for remediation if mitigation is not installed correctly.
- Further investigation should be carried out to establish the influence of other built environment professionals on bat roost mitigation implementation rates. Awareness should continue to be raised among project managers, architects, planning professionals and construction professionals about bats, bat roost mitigation and the importance of accurate installation of the latter.
- Metadata relating to licensed development work (including pre-, during and post-development data) should be systematically collected/collated into a database as part of the licensing process to allow for future analysis of the level of implementation of different provisions.
- Licensing databases should include a way for ecological consultants to make and record valid, last minute, minor mitigation design changes due to site-specific factors.
- SNCBs should be provided with adequate resources to monitor compliance with licence conditions and carry out enforcement in cases of non-compliance (absence, deviation or longer-term damage of bat roost mitigation features) because licence conditions are legally binding.
- Any improvements in the practice of ecological consultants could be facilitated in the longer-term through the Earned Recognition Project, a partnership project involving NE, BCT and the Chartered Institute for Ecology and Environmental Management (CIEEM). Sufficient resources should be dedicated to the continuation of this project.

# 4.0 Effectiveness of bat provision type

## 4.1. Background

Licensed bat mitigation strategies usually include the deployment of artificial compensation roosts to offset the loss of baseline roosts (Mering and Chambers, 2014). However, the cost of such provisions can be disproportionately high compared to the development budgets of small schemes (Mackintosh, 2016). Stone *et al.* (2013) predicted that approximately £4.13 million was spent on such provisions between 2003 and 2005. Furthermore, low-levels of effectiveness and negative press stories may also cause developers, roost owners and the wider public to lose confidence in bat conservation endeavours (Mackintosh, 2016). Nevertheless, such negative opinions could be countered if new provisions were demonstrated to be effective (Mackintosh, 2016).

The effectiveness of conservation programs represents the degree to which they achieve intended outcomes and is ultimately informed by accurate impact assessments and knowledge of associated mitigation and implementation (USAID, 2018). However, if evidence of such effectiveness is not available, ecological practitioners and decision-makers throughout the profession may not only miss opportunities for replicating effective measures, but also risk investing in ineffective or inefficient ones (Moller *et al.* 2016, USAID, 2018). Therefore, evidence-based mitigation methods and conservation policies are key for efficiently and effectively conserving bat populations (Stone *et al.* 2013, Lintott and Mathews, 2018). However, evidence regarding the effectiveness of most bat mitigation techniques and provisions is largely experiential (Stone *et al.* 2013, Mering and Chambers, 2014, Moller *et al* 2016, Lintott and Matthews, 2018). Indeed, Lintott and Matthews (2018) reported that only 11% of the 228 ecological practitioners they surveyed considered there to be sufficient evidence available to allow fully-informed decisions about bat mitigation.

The lack of such evidence is not limited to bat mitigation and the increasing sums of money being spent on such endeavours, but without systematic assessments of their effectiveness, is a familiar issue in conservation (Sutherland *et al.* 2009). Defra's review of the Conservation Regulations concluded that they were broadly fit-for-purpose, but recommended that mitigation effectiveness for protected species licences be evaluated (Defra, 2012). Several studies have examined the effectiveness of bat mitigation schemes in the UK (Briggs, 2004; Aughney, 2008; Waring, 2011; Hodgkins, 2012; Stone *et al.* 2013; Mackintosh, 2016). Most recently, Lintott and Matthews (2018) evaluated the success of 90 mitigation schemes between 2006 and 2014.

Hodgkins (2012) reported on a project by the National Trust to critically appraise bat mitigation success following building work at 40 sites, reporting bats to be present at 84%. A recent study by Garland *et al* (2017) described the structural details of a bat house where a maternity colony of roosting brown long-eared bats was successfully re-established. However, the results from other studies were less positive. Waring (2011) investigated 20 post-mitigation sites in Snowdonia, reporting that only one site was considered a full success because bats were present in the same quantity, exhibiting the same kind of use and mitigation was provided as described. Stone *et al* (2013) examined post-development monitoring data from 75 licence return forms for schemes between 2003 and 2005, reporting that bats were present at 53% of post-mitigation sites, but also that where such presence occurred there was a significant reduction in bat abundance. Mackintosh (2016) examined 27 Scottish sites where maternity roosts were affected between 2011 and 2014, reporting that maternity colonies had re-established at less than 20% of sites, and that bat presence had not been retained at 60% of sites.

Artificial roosts are structures designed and installed specifically for bats (Mering and Chambers, 2014). They have been used for scientific research, public engagement, population monitoring and habitat enhancement (Boyd and Stebbings, 1989; Mering and Chambers, 2014). They are also used as compensation for the removal of, or damage to, naturally occurring roosts (Mitchell-Jones, 2004; Mering and Chambers, 2014).

Numerous studies have reviewed and assessed artificial roosts (Lintott and Matthews, 2018; Mackintosh, 2016; McAney and Hanniffy, 2015; Mering and Chambers, 2014; Stone *et al* 2013; Poulton, 2006; Briggs, 2004; Swift, 2004) in an effort to empirically draw conclusions about their effectiveness. Flaquer *et al* (2006) and Poulton (2006) both demonstrated that the physical attributes of new provisions such as location, aspect and size were related to occupancy rates. This is probably because they influence internal temperature and humidity (Mackintosh, 2016). Likewise, Briggs (2004) recommended that a roost provision's location, temperature, volume, artificial light levels and post-development disturbance were important considerations. Indeed, thermal conditions inside roosts are likely to play an important role in roost selection (Ngamprasertwong *et al.* 2014), particularly for maternity colonies, due to the higher energy demands of pregnancy and lactation (Entwistle *et al.* 1997; Kerth *et al.* 2001). Lower roost temperatures are also more likely to induce torpor in temperate zone bats which can delay the development of embryos and offspring (Bartonicka and Rehak, 2007). There is evidence that different species select artificial roosts that most resemble their natural roost structures (Stone *et al* 2013; Mering and Chambers, 2014). For example, Griffiths *et al* (2018) demonstrated that chainsaw hollows were consistently warmer than ambient conditions at night and more similar to the thermal profiles of tree hollows compared to timber bat boxes.

It has been proposed that high foraging activity in the vicinity of roosts may increase the likelihood that new provisions are discovered by bats (Lintott and Matthews, 2018). Likewise, if bats are present in the local area then bats may colonise new roost provisions more rapidly (Mering and Chambers, 2014). However, although roost uptake and colonisation times may be related to local roost densities and bat population sizes (Mering and Chambers, 2014; Lintott and Matthews, 2018), such a relationship has not been proven (Hayes and Loeb, 2007).

Previous bat mitigation reviews indicate that bat boxes not only account for most newly installed provisions in UK mitigation schemes (Stone *et al.* 2013; Mackintosh, 2016; Lintott and Matthews, 2018), but also provide readily available evidence regarding compensation roost design and effectiveness (Moller *et al.* 2016). However, it is generally accepted that bat boxes do not adequately compensate for the removal of significant maternity roosts, even though they may provide adequate replacements for roosts of lower conservation status (Mitchell-Jones, 2004; McAney and Hanniffy, 2015; Moller *et al.* 2016; Rueegger, 2016). Although an effective tool for certain conservation goals (McAney and Hanniffy, 2015), most studies have demonstrated that bat boxes are most effective for more widespread, abundant and generalist species of lower conservation concern (Mering and Chambers, 2014; Griffiths *et al.* 2017; Moller *et al.* 2016) and unlikely to be effective at retaining maternity colonies (Mackintosh, 2016; Lintott and Matthews, 2018).

Nevertheless, some studies (Meddings *et al.* 2011; Lintott and Matthews, 2018) have reported that bat box frequencies are positively correlated with occupancy rates. Likewise, Poulton (2006) reported significant differences in terms of bat box models, with woodcrete boxes generally having higher occupancy rates compared to timber designs, whilst Flaquer *et al.* (2006) documented a 95% success rate for boxes made from laminated wood. In contrast to bat boxes, previous studies suggest that schemes with bat lofts were more effective at retaining bats (Stone *et al.* 2013; Lintott and Matthews, 2018). Lintott and Mathews (2018) also reported a relationship between the number of roost entrances in bat lofts and *P. auritus* presence.

Despite the pervasive use and associated costs of new roost provisions in mitigation schemes (Stone *et al.* 2013; Mackintosh, 2016), most evidence regarding their effectiveness as a mitigation tool is based on experience rather than empirical evidence (Stone *et al.* 2013; Mering and Chambers, 2014). Therefore, BCT's Mitigation Project included the systematic collection of field data regarding new roost and access point provisions. A key project aim was to use empirical evidence to inform future decisions regarding provision choices, positioning and design measures as well as supporting the production of any updated bat mitigation guidelines. Section 4 therefore reports on the following project aims:

- Evaluate the effectiveness of new roost and access point provisions (i.e. compensation roosts) in terms of bat occupancy rates.
- Investigate any underlying associations between effectiveness and particular attributes, including roost positioning, design features, provision frequency and bat activity levels.

## 4.2. Methods

### 4.2.1. Structural attributes

Surveyors recorded data on numerous structural attributes during daytime assessments. These were assigned to one of four levels: 1) site; 2) host structure; 3) roost; and 4) access point. More information is provided in Table 4.1.

**Table 4.1.**

*List of attributes recorded in relation to roosting provisions*

| Data level | Attribute |
|---|---|
| Site | Bat activity levels. The average number of bat calls during night-time emergence surveys |
| Host structure | Maximum building height (m).<br>Building footprint ($m^2$).<br>Total number of new roosting provisions installed.<br>Building age. Categorised as either: 1) new buildings; or 2) retained / modified buildings.<br>Level of human use. Categorised as either: 1) occupied buildings used by people for living or working; or 2) disused or partially used outbuildings.<br>Intended ecological function. Categorised as either: 1) bat houses; or 2) other non-bat houses (i.e. all other buildings not specifically dedicated for bats).<br>Trees (with bat boxes) |
| Roost (all) | New, retained, modified or non-intended (see Appendix 1 for glossary of definitions)<br>Aspect / orientation: Categorised as N, NW, W, SW, S, SE, E or NE.<br>Height above ground-level (m).<br>Materials.<br>Internal height (m).<br>Internal volume ($m^3$).<br>Number of access points. |
| Roost (voids only) | Void category. Bat lofts were dividing into one of three sub-groups: 1) new lofts within new host builds; 2) new lofts within adapted builds (e.g. loft conversions); and 3) modified voids.<br>Wall and roofing materials including roof lining and insulation.<br>Void dimensions – height (m) and volume ($m^3$)<br>Internal light levels (scale of 1-3)<br>Internal obstructions to flight (scale of 1-3)<br>Exposure to weather (scale of 1-3)<br>Internal temperature relative to exterior (°C). Measured using a hand-held thermometer and compared to external ambient temperature readings taken shortly before or afterwards. |

| | |
|---|---|
| | Diversity of small internal cavity sub-groups. Assigned a value of 1-8 according to the presence or absence of the following eight types of PRF: internal bat boxes; wall cladding and boarding; gaps behind lintels; roof lining (including sarking); wall stonework; exposed timbers; chimney stacks; and cavity walls. |
| Roost (bat boxes only) | Bat box model type.<br>Box mounting location: Boxes were categorised as either 1) tree-mounted; 2) wall-mounted; or 3) wall-integrated. |
| Access point | Aspect / orientation: Categorised as N, NW, W, SW, S, SE, E or NE.<br>Height above ground-level (m).<br>Access point width (mm). |

When comparing different types of roosting provision (for example, certain bat box models) bat occupancy rates were taken as the proportion where bats were present relative to the total number surveyed. Some parts of our analysis also distinguish between general occupancy rates and instances where live bats emerging or *in-situ* (rather than droppings) were also used to assign presence. However, the presence of bat droppings in roosts were generally used to assign presence only unless indicated otherwise. For access points, most openings were only assigned as 'present' or 'active / in-use' if surveyors visually observed bats fly in / out of the entrance. Exceptions were structures like bat boxes where the presence of bats indicated their use of the single access point.

### 4.2.2. Numbers of roosting provisions

The number of roosting provisions varied considerably between sites. Overall, 849 roosts and / or roosting provisions and 1736 access points were surveyed. Table 4.2 and Figure 4.1 provide a breakdown of these provisions.

**Table 4.2**

*Breakdown of roost and access point provisions surveyed by BCT*

| Provision type | Roosts | | Access points | |
|---|---|---|---|---|
| | Gross frequency | Gross occupancy rate | Gross frequency | Gross use-rate |
| New provisions | 698 | 18% | 1629 | 8% |
| Modified | 64 | 52% | 12 | 8% |
| Retained | 36 | 25% | 34 | 21% |
| Non-intended | 51 | 100% (by definition) | 61 | 100% (by definition) |

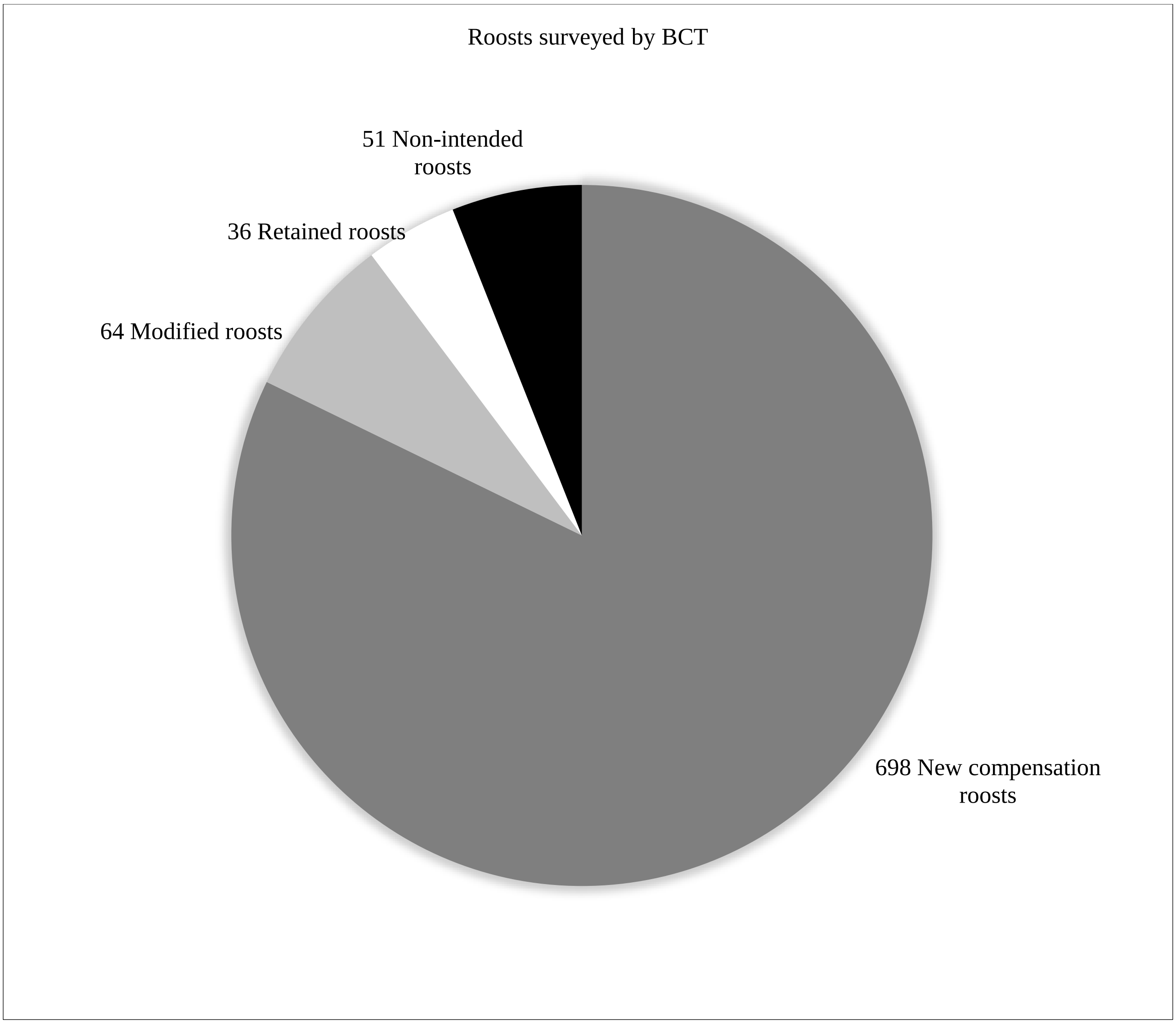



**Figure 4.1.**

*Breakdown of roosts surveyed by BCT during the project*

In addition, 101 roost structures were searched for but were missing – either because they had not been installed to begin with, the structure had been removed during the intervening time period or insufficient baseline information was available to find them. This aspect of implementation is examined further in Section 3 of this report.

### 4.2.2. Internal void attributes

We examined the relationship between four internal bat loft void attributes and bat abundance counts for each loft sub-group. These included: 1) internal height (m); 2) internal volume ($m^3$); 3) internal temperature relative to exterior (ºC); and 4) diversity of small internal cavity sub-groups.

### 4.2.3. Smaller cavity roosts

Smaller cavity roosts were variable and more numerous. They were broadly classified as being either 1) external; or 2) internal if they were accessed from an internal void or crawling space. These roosts were further sub-categorised according to their structure and location. Note that the following roost categories are not intended to be exhaustive and simply represent the structures encountered during this project.

- Bat boxes. Grouped further into: 1) tree-mounted boxes; 2) wall-integrated boxes; and 3) wall-mounted / hanging bat boxes.
- Boarding / panels. Grouped further into: 1) cladding; 2) weatherboarding; and 3) other boarding.
- Cavity walls.
- Exposed internal timbers. Includes gaps behind internal ridge boards.
- Internal gaps in lining and insulation.
- Inter-tile / lining cavity.
- Lead flashing.
- Ridge void.
- Soffit boxes.
- Underneath tiles. Grouped further into: 1) hanging tiles; 2) field tiles; 3) hip tiles; and 4) edge tiles.
- Stonework and brickwork.
- Wall top crevices. Grouped further into 1) eaves wall tops and 2) gable wall tops.

### 4.2.4. Access points

Access points were distinguished from roosts in this study and were specifically the opening apertures leading into roosts. They were broadly classified as being either 1) external; or 2) internal if they were accessed from an internal void space. Access points were further sub-categorised according to their form and location. Note that the following access point categories are not intended to be exhaustive and simply represent the openings encountered during this project.

- Bat bricks (or similar).
- Bat box access points. Grouped further into: 1) bespoke entrances; and 2) openings integrated into ready-made models.
- Behind lintels, doorways and window frames.
- Boarding and panels. Grouped further into: 1) cladding; 2) louvred slats; and 3) other timber boarding.
- Exposed internal timbers. Includes gaps behind internal ridge boards.
- Internal crawl spaces / gaps. Grouped further into: 1) gaps in roof lining and insulation; and 2) solid crawl spaces.
- Larger openings: grouped further into: 1) cellar entrances; 2) dormer access; 3) internal openings; 4) open window / door; 5) other external fly-in access; and 6) vent access.
- Lead flashing.
- Stonework gaps. Grouped further into walls and chimneys.
- Tiles. Grouped further into: 1) bat tiles (specifically installed to attract bats); 2) edge tiles; 3) field tiles; 4) hanging tiles; 5) hip tiles; and 6) ridge tiles.
- Wall tops. Grouped further into: 1) gaps behind bargeboards; 2) gaps behind fascia panels; 3) eaves gaps; 4) gable apex gaps; 5) gable verge gaps; 6) internal dividing walls; 7) soffit box gaps.

We examined the relationship between access point frequency and bat occupancy rates and abundance counts. This was achieved by investigating the outcome variables for bat lofts, wall tops and ridge voids in isolation. Not only did these roost structures generally have the highest occupancy rates, but they also typically featured more than one access point. In contrast, provisions like gaps in stonework or bat boxes typically only featured one access point per roost. Only new access points were used for this part of the analysis, although the host structure may have been a modified roost with retained / original access points intact.

### 4.2.5. Assigning conservation outcomes

Eight different criteria were used at the site-level and referred to here as ‘conservation outcomes’ for bats. These measures were devised for this project as a means of broadly assessing the degree to which sites, as a whole, retained bats post-development compared to the baseline stage. The different criteria accounted for the fact that sites typically featured multiple roosts and bat species during baseline assessments and possibly monitoring assessments as well. These are described in Table 4.3. Note that outcomes 1-8 have not been ranked in any particular order and the application of each is likely to be site-specific.

**Table 4.3**

*Criteria for assessing the retention of bats on site post-development*

| **Conservation outcomes for bats at the site-level** | |
|---|---|
| Outcome | Description |
| 1 | Site retained the presence of roosting bats - any species. |
| 2 | Site retained the presence of *any* target bat species. |
| 3 | Site retained the presence of *all* target bat species. |
| 4 | Site maintained or increased overall bat abundance levels (via direct counts) - regardless of species. |
| 5 | Site maintained or increased abundance levels of *at least one* target bat species. |
| 6 | Site maintained or increased abundance levels of *all* target bat species. |
| 7 | Site maintained or increased bat species richness on site (i.e. number of different roosting bat species). |
| 8 | Site maintained or increased the value of baseline roost(s) with the highest conservation status (Table 4.4). |

Outcome 8 used 'Figure 4. Guidelines for proportionate mitigation' on page 39 of English Nature's Mitigation Guidelines (Mitchell-Jones 2004) to quantify a site's conservation status. Table 4.4 displays the ranked criteria used in the assessment. Since Outcomes 5-6 related to abundance levels, this was taken as the maximum bat count recorded during a single occasion to avoid overestimating numbers. Where several species were recorded, Outcome 4 was taken as the sum-total of all single-species counts. Where only bat droppings were recorded, this was given the same weight as a single bat to allow comparison with abundance counts.

Presence/absence was used for comparing the presence of one or more bat species roosting at a particular location (site, building, roost or access point) or time period. Where only bat droppings were recorded, this was taken as 'present' unless stated otherwise. The record of sonogram information from static detectors located outside access points or inside open voids like open barns or garages was not taken as presence of bats using a roost unless accompanied by other evidence. When comparing different types of roosting provision (for example, certain bat box models), bat occupancy rates were taken as the proportion where bats were present relative to the total number surveyed.

Bat abundance levels were used for comparing the bat counts of one or more species. It was generally taken as the maximum number of bats recorded. For making before-and-after comparisons, baseline results where numerous surveys took place were generally combined so the abundance level was simply the maximum number recorded on a single occasion. Where post-development monitoring results included data from both the consultant and BCT monitoring stages, these results were also combined unless direct comparisons were being made between the two monitoring stages. Where only bat droppings were recorded, this was taken as a single bat to facilitate quantitative analysis. Note that surveyors occasionally recorded bat droppings in relatively high densities and the presence of other signs (e.g. oil marking on wood) may have indicated a maternity roost or higher bat abundance counts at other times of the year. Although such observations were always documented, dropping densities were not used to infer bat abundance as this would have introduced surveyor subjectivity.

Roost status was broadly classified as being 'higher' or 'lower' status. These were taken from 'Figure 4. Guidelines for proportionate mitigation' on page 39 of English Nature's Mitigation Guidelines (Mitchell-Jones 2004). Lower status roosts included night-roosts, day roosts and also transitional or mating roosts as per Levels 1-5 in Table 4.4. Higher status was reserved for roosts hosting maternity colonies. Since BCT's monitoring stage took place during the maternity season in both Years 1 and 2, no hibernating bats were recorded.

**Table 4.4**

*Criteria for assessing a roost's conservation status*

| **Highest conservation status of bat roost(s) on site** | |
|---|---|
| Level | English Nature description |
| 1 | Feeding perches of common / rarer species* |
| 2 | Individual bats of common species |
| 3 | Small numbers of common species. Not a maternity site. |
| 4 | Feeding perches of Annex II species. |
| 5 | Small numbers of rarer species. Not a maternity site. |
| 6 | Hibernation sites for small numbers of common / rarer species. |
| 7 | Maternity sites of common species. |
| 8 | Maternity sites of rarer species. |
| 9 | Significant hibernation sites for rarer / rarest species or all species assemblages. |
| 10 | Sites meeting SSSI guidelines. |
| 11 | Maternity sites of rarest species. |

*For the purposes of this assessment, 'common' species include *P.pipistrellus*, *P.pygmaeus* and *P. auritus*. All other species (including *M. nattereri*) have been classified as 'rarer' in this project.

The time period used to study the degree to which bat occupancies may change over time was measured as the number of months between installation and when surveys were concluded. Survey data was therefore recorded from two distinct time periods – the consultant and BCT monitoring stages. Where multiple surveys took place, time was always taken to be the earliest date at which bats or maximum abundance levels were first recorded. Where no roosting bats were recorded, the time was simply taken as the date of the final survey.

### 4.2.6. Examination of possible sample bias

Our sample was inevitably influenced to some degree by both BCT (as the researcher) and roost owners (who self-selected their properties for survey). However, the potential influence of ecological consultants and SNCBs was also present for some sites but not others. The extent of any associated bias depended on whether SNCBs or ecological consultants played an active role contributing reports or inviting roost owners to participate. Sites were therefore broken down according to the sources of assistance by which case studies were made available to BCT:

- SNCBs only – 30
- Ecological consultants only – 22
- SNCBs and ecological consultants - 19

We investigated any significant differences in mitigation efficacy between case studies provided with the assistance of these three sources. Mitigation efficacy was measured using the total number of conservation outcomes (0-8) met at each site. This total was compiled for the consultant and BCT monitoring stages separately for each site and both were compared for each source of assistance. Since certain sites did not receive any survey effort during the consultant monitoring stage, these were excluded from comparisons.

### 4.2.7. Statistical Analysis

We explored our dataset to reveal any noticeable or quantifiable relationships between attributes. However, since the dataset was constructed from real-world monitoring data, it is acknowledged that no controls had been put in place to isolate cause-and-effect relationships. Although any relationships are purely correlational, particularly strong or noticeable relationships can nonetheless offer useful insight into the underlying factors that may be affecting provision effectiveness (Poulton, 2006).

The bat function attributes were generally used as the outcome variable in the statistical tests used in this report. However, the Shapiro-Wilk test and preliminary analysis confirmed they generally violated the underlying assumptions of certain parametric tests such as T-tests and Analysis of Variance (ANOVA). This was because they generally exhibited a non-normal distribution and a departure from homogeneity of variance. Such outcomes are reasonably common in ecological studies when the target organisms are relatively rare. Although T-tests were used on occasions where the data did not violate such assumptions, other methods were typically used in the analysis.

For certain research questions, we used the Wilcoxon matched pairs test to examine differences between groups, or repeated measures analysis when examining data from distinct time periods. However, presence-absence data was typically analysed using a Generalized Linear Mixed Model (GLMM) with a logistic link function and binomial error distribution. Count data were analysed with a log-normal mixed model (taking the log of counts+1), which was preferred to a Poisson GLMM due to the high level of over-dispersion in the count data. All mixed models were fitted using Residual Maximum Likelihood (REML) in order to avoid the bias in variance components that can arise from Maximum Likelihood estimation with small sample sizes (Welham et al. 2015). Continuous variables such as height were fitted using both linear and quadratic terms, log-transforming where the distribution was skew, but only the linear test is reported where the quadratic term was non-significant.

We used the following standards to interpret p-values in significance tests:

- $p > 0.05$ = Not significant
- $p < 0.05$* = Marginally significant
- $p < 0.01$** = Moderately significant
- $p < 0.001$*** = Highly significant

All statistical analysis was completed using GenStat 19.1 for Windows by VSNI.

## 4.3. Results

### 4.3.1. Baseline data

Our desk-study exercise documented 119 buildings and 409 bat roosts that had been directly or indirectly affected by licensed bat mitigation schemes. These roosts included those recorded during baseline surveys as well as those reported by ecological consultants in licence reports following capture / exclusion work and soft-strip operations.

Roost numbers varied considerably between sites, from smaller sites with single roosts to larger and more complex sites with multiple roosts. Figure 4.2 shows the species composition of roosts recorded during the baseline stage. *P. pipistrellus* roosts were affected most frequently and represented 33% (n = 409) of the sample, followed by *P. auritus* at 22%.

*P. auritus* was responsible for the largest proportion of higher-status roosts (40%, n = 57). These were predominantly maternity roosts, with only a single *P. auritus* hibernation roost recorded during baseline surveys for lower numbers of bats. All higher-status *Pipistrellus* spp and *Myotis* spp roosts were maternity rather than hibernation roosts.

Although higher status maternity roosts were recorded at 42% of sites (n=71) during the baseline stage, such roosts only accounted for 14% (n = 409) of the total roost count in our data set. This was because most of these sites also featured a larger number of lower-status day roosts as well.

In terms of the roost structures themselves, 15% were voids (including loft or outbuilding voids) and 77% were smaller cavities. Specifically, 24% of these smaller cavities were internal ones accessed by bats from inside larger voids. The remaining 8% were unknown or ambiguous structures.

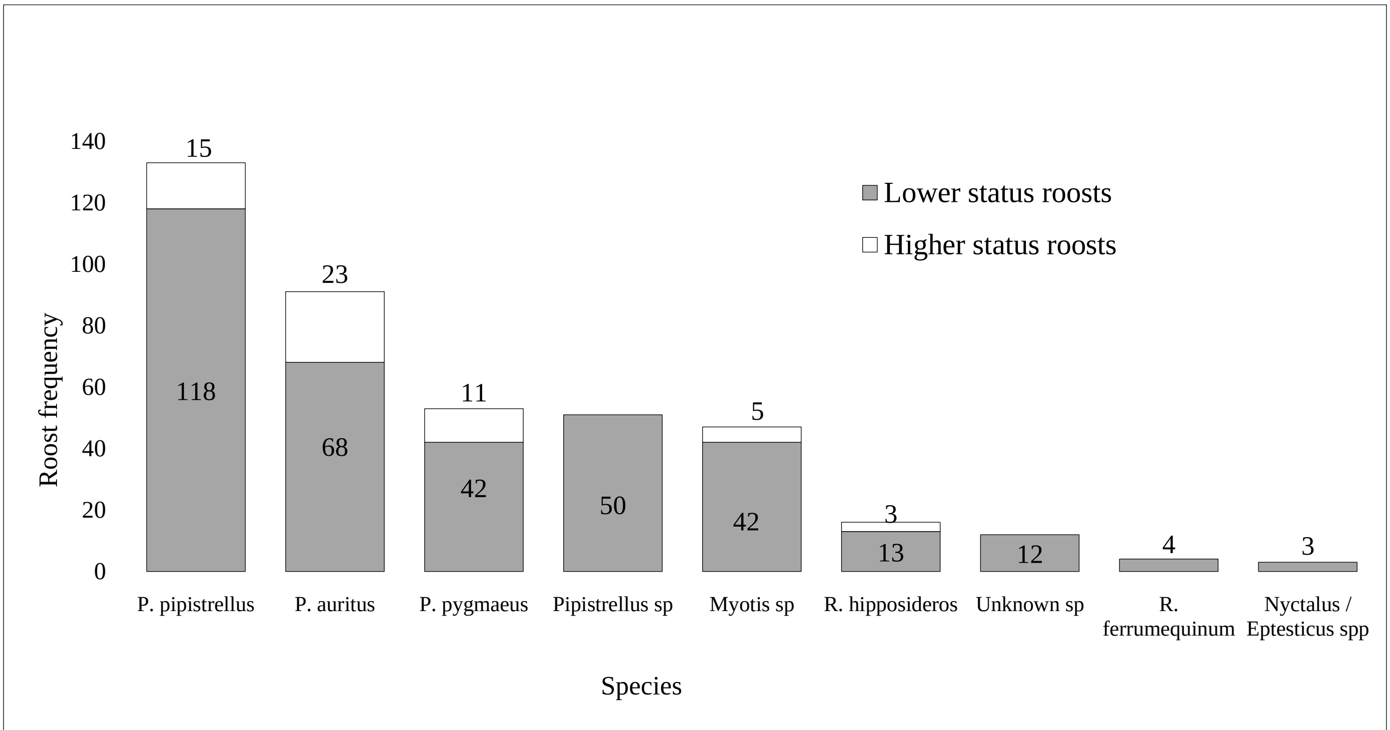



**Figure 4.2**

*Species affected during baseline stage*

In terms of impacts, most sites (83%) included the removal of at least one roost, while a smaller proportion (10%) were wholly based around roost modification measures. Overall, 208 active bat roosts were recorded during BCT's post-development monitoring surveys.

### 4.3.2. Occupancy Rates for Different Roost Groups

Overall, occupancy rates for bat presence during monitoring are displayed in Figure 4.3 and varied considerably between the three broad roost groups. This was confirmed by the GLMM mixed model where presence rates between groups were significant (chi-squared=12.19 with 2 d.f., p = 0.002**). Void occupancy rates (35%, n = 43) were noticeably higher than the gross average rate of 18% (n = 698). Bat presence rates for small external cavities were marginally above the gross average at 22% (n = 471). Small internal cavities were the least effective overall with an average rate of 6% (n = 184).

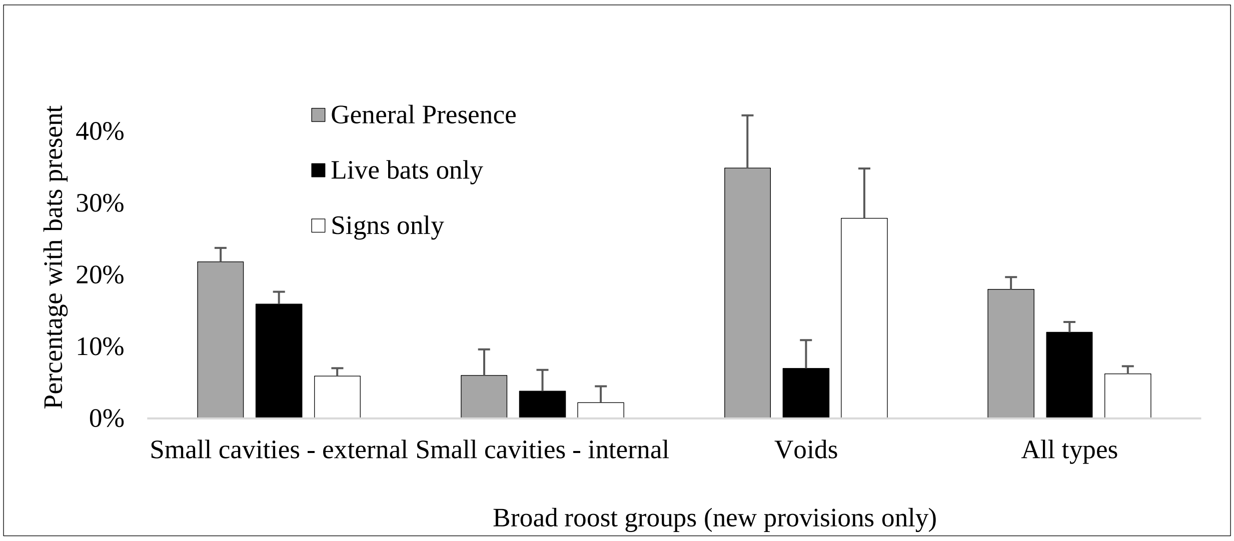



**Figure 4.3.**

*Bat occupancy rates of new provisions for each broad roost group*

Bat presence rates for small cavities were determined by live bats (as opposed to signs only) more frequently than voids, where presence was indicated more frequently by signs only. Again, this was confirmed when the GLMM model only considered instances of live bats for assigning presence. Although there continued to be a significant difference between roost groups (chi-squared = 8.39 with 2 d.f., p = 0.015*), small external cavities were more effective than voids using this measure (16% and 7 % respectively). Therefore, despite technically having the highest bat occupancy rate overall, most instances of bat presence in voids were determined by signs alone rather than live bat records.

We compared bat occupancy rates for the most frequently installed roost sub-groups (Figure 4.4). Apart from bat lofts and bat boxes, other roost sub-groups were more varied and installed at noticeably lower frequencies or at less sites. However, the next most frequent sub-groups were gaps in wall stonework and brickwork, wall top crevices (at the eaves or gables), internal boarding and panels, ridge voids and the inter-tile / lining cavities underneath roof coverings. Despite certain sub-groups appearing to be relatively effective (for example, bats were recorded in 27% of external cladding provisions, n=11), such structures were installed too infrequently to perform meaningful comparisons.

The GLMM model reported that bat occupancy rates varied considerably between sub-groups and differences were significant, both for overall presence (chi-squared = 25.50 with 10 d.f., p = 0.004**) and rates for live bats only (chi-squared = 26.01 with 10 d.f., p = 0.004**).

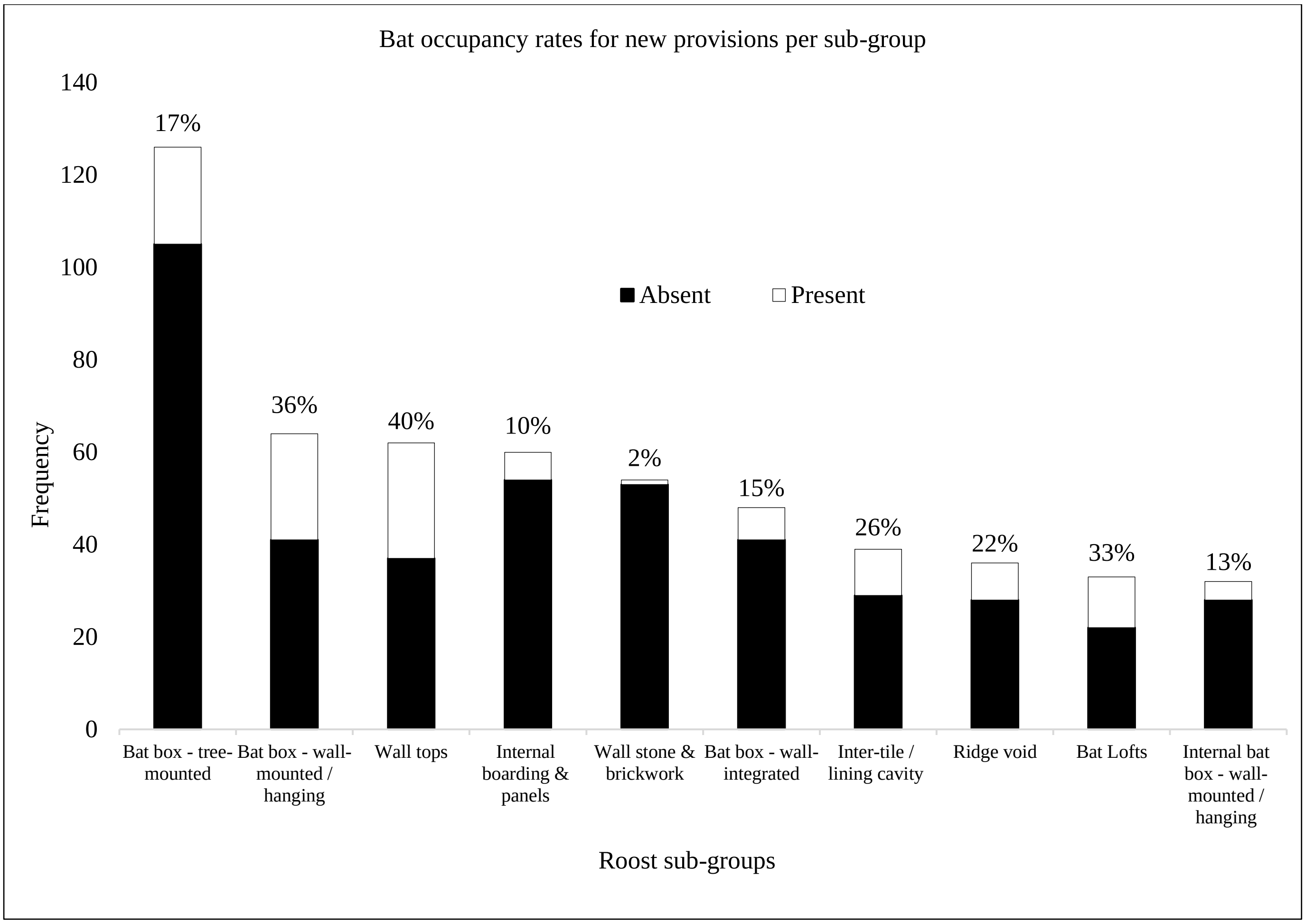



**Figure 4.4**

*Bat occupancy rates of new provisions for each broad roost sub-group*

Bats were recorded most consistently at wall top crevices, followed by wall-mounted bat boxes, new bat lofts, inter-tile / lining cavities and ridge voids. Bats were recorded least frequently in stone and brickwork gaps, internal bat boxes, internal boarding / panels and tree-mounted bat boxes. As noted above, internal small cavity roosts as a whole were consistently less effective than external small cavities and voids in terms of bat presence.

### 4.3.3. Species Composition for Different Roost Groups

Figure 4.5 shows the species composition for the three broad roost groups. Chi-squared tests for new provision occupancy rates indicated highly significant differences in selection of broad roost groups between species (chi-squared = 67.86 with 9 d.f., $p < 0.001$***). This was predominantly due to the differences between *Pipistrellus* spp / *Myotis* spp and *P. auritus*, which was recorded in voids more consistently (see Section 5). Indeed, 80% (n = 15) of occupied voids were determined by the presence of *P. auritus*. This species was also responsible for occupying the largest proportion of small internal cavities (64%, n=11). *Pipistrellus* spp were largely recorded in small external cavities, with 87% (n = 102) of occupied external cavities being used by this genus compared to *P. auritus* and *Myotis* spp (5% and 6% respectively).

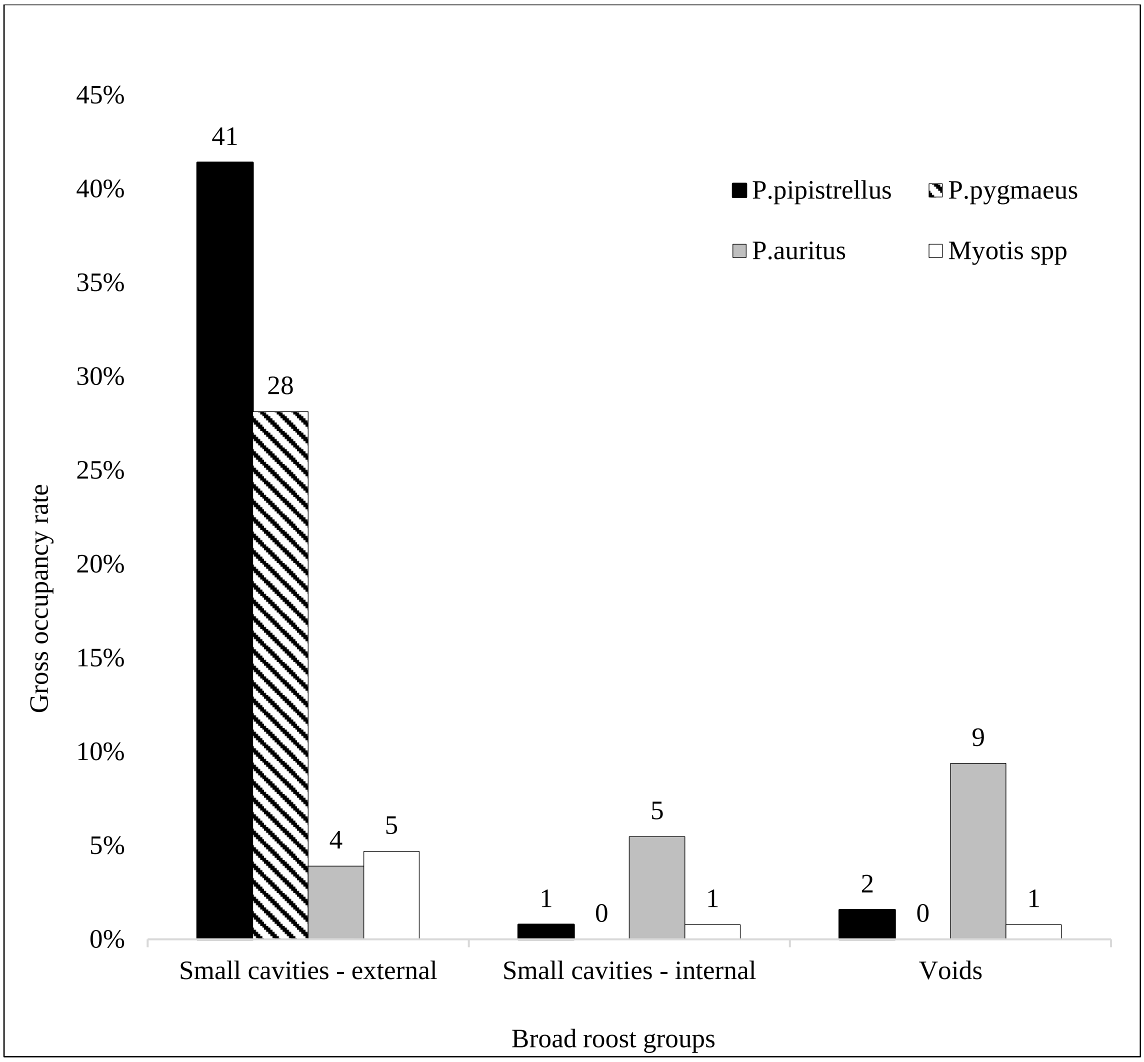



**Figure 4.5**

*Species composition of bats using new provisions*

When live bats were recorded, abundance counts varied between 1 and 84 bats. The gross average count across all provisions with live bats was 5.0 bats (n = 85): 2.3 for voids (n = 3), 5.3 for small external cavities (n = 75) and 3.1 for small internal cavities (n = 7). Inter-group differences in bat abundance counts for new provisions were examined using a REML model for the log-transformed data. The model confirmed that differences between roost groups were of borderline significance (F = 3.01 with 2 and 553 d.f., p = 0.05*) with small external cavities having the highest abundance levels. However, the accuracy of such analysis was constrained by: 1) the extreme variability of live bat counts; and 2) live bats being present in a higher proportion of small external cavities compared to the other groups. Indeed, if the REML model included all roosts where bats were present (including instances of signs only), differences were not statistically significant (F = 1.68 with 2 and 89 d.f., p = 0.192).

### 4.3.4. Conservation Outcomes

Post-development monitoring data from both the consultant and BCT monitoring stages were combined and broadly assessed in terms of the eight conservation outcomes in Table 4.3. Table 4.5 shows the percentage of sites meeting each of the outcomes.

**Table 4.5.**

*Percentage of sites meeting the different conservation outcomes*

| **Conservation outcome** | | **%** |
|---|---|---|
| Roosting bats not retained at all | | 14 |
| Site retained the presence of roosting bats | *Any* species | 86 |
| | *Any target* species | 79 |
| | *All target* species | 34 |
| Site maintained or increased overall bat abundance levels (via direct counts) | *Any* species | 35 |
| | *Any target* species | 49 |
| | *All target* species | 13 |
| Site maintained or increased bat species richness on site | | 49 |
| Site maintained or increased the value of baseline roost(s) with the highest conservation status | | 44 |

86% (n = 71) of sites met at least one outcome, retaining roosting bats to some extent. Only 13% of sites maintained or increased the abundance levels of all target species. Inevitably, these sites also met the other seven outcomes by default and may therefore be perceived as being ‘wholly successful’. 14% of sites did not retain roosting bats or meet any of the conservation outcomes, so could be perceived as being ‘non-successful’

### 4.3.5. Roof lofts and voids

Bat lofts were examined in more detail by dividing them into three sub-groups: 1) new bat lofts within new host builds; 2) new lofts within adapted builds (e.g. loft conversions); and 3) modified bat lofts where baseline roosts had been identified and the structure largely retained. Occupancy rates for voids were either obtained from bats roosting openly in the voids themselves, or roosting in other more cryptic internal cavities inside them. Therefore, any occupied small external cavity roosts within the same host buildings were excluded from this part of the assessment. Table 4.6 shows occupancy rates for the different sub-groups.

Since bat lofts were typically to compensate for lost *P. auritus* and / or *Myotis* spp roosts, we compared post-development monitoring counts for these species to that recorded during baseline assessments at the respective parent sites. This was completed for each of the three bat loft sub-groups. If sites did not originally feature loft voids, baseline counts were simply taken from the roost or host building for which new bat lofts were acting as compensation. Where the number of lofts removed exceeded the number of compensatory bat lofts, bat counts from the baseline stage were combined

As described above, bat lofts were one of the most effective new provision sub-groups in terms of bat presence (occupancy rates of 33%, n = 33). They were particularly effective for *P. auritus* presence and this species was responsible for 73% of occupied bat lofts (n = 11).

**Table 4.6**

*Occupancy rates for bat loft sub-groups*

| Bat Loft Sub-Groups | Effectiveness | | | | |
|---|---|---|---|---|---|
| | Occupancy rate (presence) | Occupancy rate (live bats only) | Min bats | Max bats | Mean no. bats (roosts with live bats only) |
| New lofts in new builds (n=13) | 0 (0%) | 0 (0%) | N/A | N/A | N/A |
| New lofts in adapted builds (n=20) | 11 (55%) | 0 (0%) | N/A | N/A | N/A |
| Retained but modified lofts (n=37) | 24 (65%) | 12 (32%) | 1 | 21 | 5 |
| Totals (n=70) | 35 (50%) | 12 (17%) | 1 | 21 | 5 |

However, it was apparent that none of the newly-created bat lofts in new host buildings presented any evidence of bat occupancy – either inside the void itself or within small internal cavities. Bats were recorded in a noticeably higher proportion of new lofts when they were integrated into retained but adapted host builds (occupancy rate of 55%, n = 20). Retained (but modified) lofts featured bat occupancy rates of 65% (n = 37), 88% of which were due to the presence of *P. auritus*.

Although overall occupancy rates for modified lofts were only marginally higher than new lofts in adapted builds, all records from these new lofts were determined by signs alone rather than live bats. Likewise, the small densities of droppings observed for these records were considered to represent lower-levels of bat use (occasional day, transitional or night-roosting) instead of maternity or regular day roosting. In contrast, live bat counts represented 32% of occupied modified lofts with *P. auritus* representing 83% of these (n = 12).

Figure 4.6 compares bat counts for *P. auritus* and *Myotis* spp for schemes using different loft sub-groups. Inter-group differences in log-transformed counts for loft sub-groups were examined using a REML model. This allowed for grouping the roosts into their respective host buildings and parent sites. There was a highly statistically significant difference between baseline and post-development monitoring counts ($F = 46.05$ with 1 and 69 d.f.,$p < 0.001$***). The magnitude of this difference also varied between loft sub-groups and was marginally significant ($F = 3.19$ with 2 and 69 d.f., $p = 0.047$*). However, this should be treated with caution because the p value was only slightly below the conventional 5% cut-off point and the residual distribution was somewhat non-normal. Furthermore, the absence of quantitative monitoring data for two of the loft sub-groups prevented any meaningful comparisons of bat abundance between loft types. Nevertheless, there was a notable reduction in the number of instances of live bat presence during post-development monitoring surveys compared to the baseline surveys.

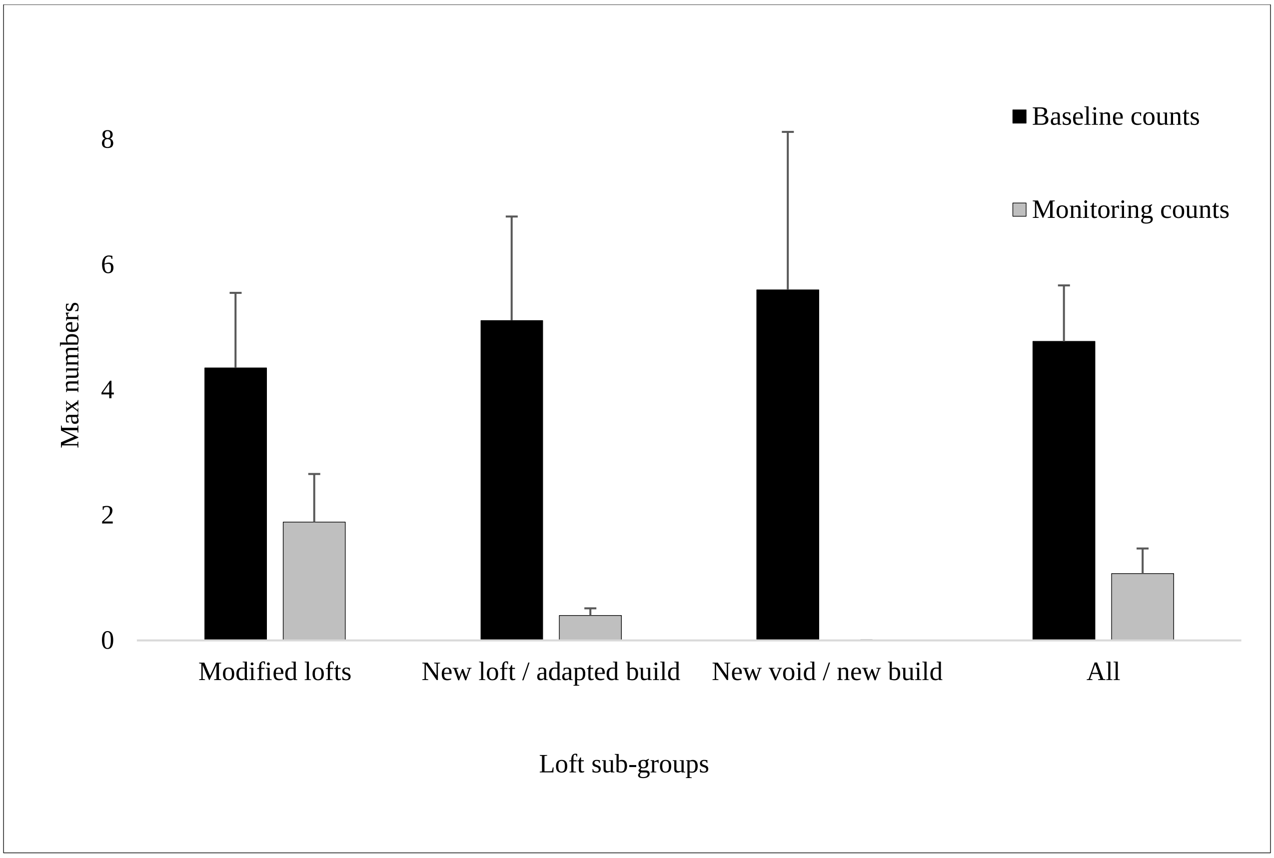



**Figure 4.6**

*P. auritus and Myotis spp count comparisons for schemes using different loft sub-groups*

Influence of internal bat loft attributes

There was no significant relationship between temperature (ºC) and bat abundance counts (F= 1.36 with 1 and 21 d.f., p = 0.257). However, the number of small internal cavity types inside voids showed a highly significant positive relationship with bat counts (F = 10.79 with 1 and 24 d.f., p = 0.003**). Similarly, internal height (m) and volume ($m^3$) both displayed significant relationships with bat counts (height F = 12.44 with 1 and 26 d.f., p = 0.002**; volume: F = 11.20 with 1 and 19 d.f., p = 0.003**). Note that this analysis was for modified loft voids only, since no count data was available for new loft voids – either in new or adapted host builds. The highest bat loft recorded was 6m; no bats were recorded in lofts in which the highest internal point was lower than 1.5m. However, since internal loft height and volume were themselves strongly correlated, it was impossible to distinguish which displayed the strongest influence. Likewise, when using a REML model to account for random effects at the respective host buildings and parent sites, there was also a high level of random variation so other causal factors such as building construction, impact type, survey effort and habitat may also have influenced the outcome.

The absence of quantitative count data for new lofts also prevented these attributes from being assessed between loft sub-groups. However, since a statistically significant difference in bat counts between loft sub-groups had already been established, the possible influence of these four attributes in new loft voids were assessed by directly comparing them to those of modified voids.

The range of values displayed in the box plots (Figure 4.7) demonstrates that modified and new lofts in adapted builds generally had slightly higher internal volumes than new voids in new builds. However, the differences in height were less noticeable, possibly because modified lofts were longer and wider, but not necessarily taller than new lofts. Although there was no significant difference in temperature values, modified lofts and new lofts in adapted builds had noticeably higher diversities of internal small cavity PRFs compared to those in new builds.  Nevertheless, the REML model indicated there were no significant difference in any of these attributes between loft-sub groups.

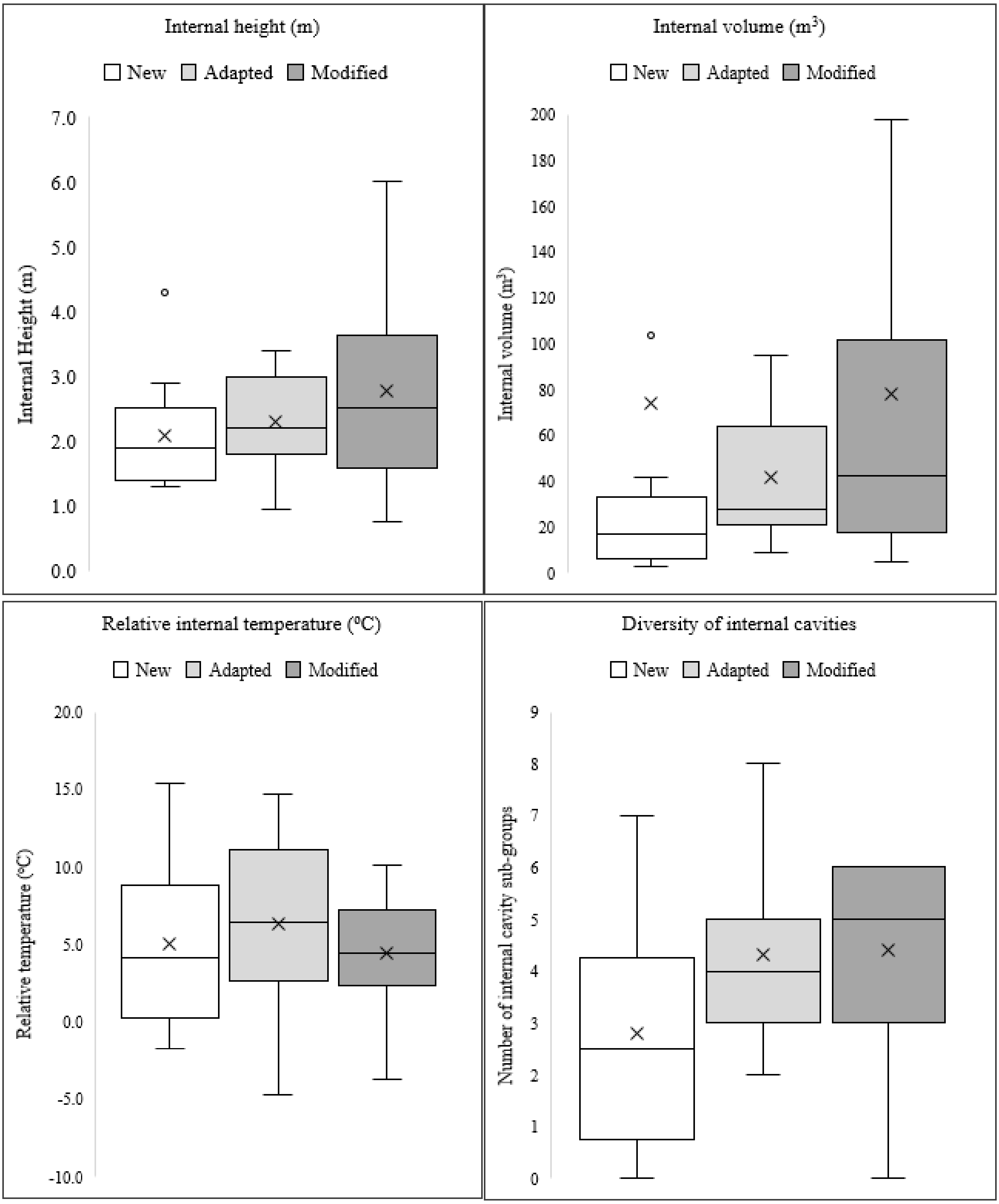



**Figure 4.7**

*Box plots comparing relative temperature, height, volume and internal cavity diversity between loft sub-groups*

Figures 4.8. and 4.9. show the relationship between loft height and abundance counts for both the baseline stage and for modified lofts during the monitoring stage. It should be noted that over half of the loft voids used at baseline stage didn't have height or volume measurement data recorded in reports or licence applications. It is also worth noting that the positive relationship between height and abundance counts for modified lofts was heavily influenced by two larger roosts with loft heights of 4 and 5.5m. These relationships should not be used to extrapolate an 'ideal' height for new bat lofts as even larger compensatory roosts generally failed to attract bats, or failed to attract comparable numbers.

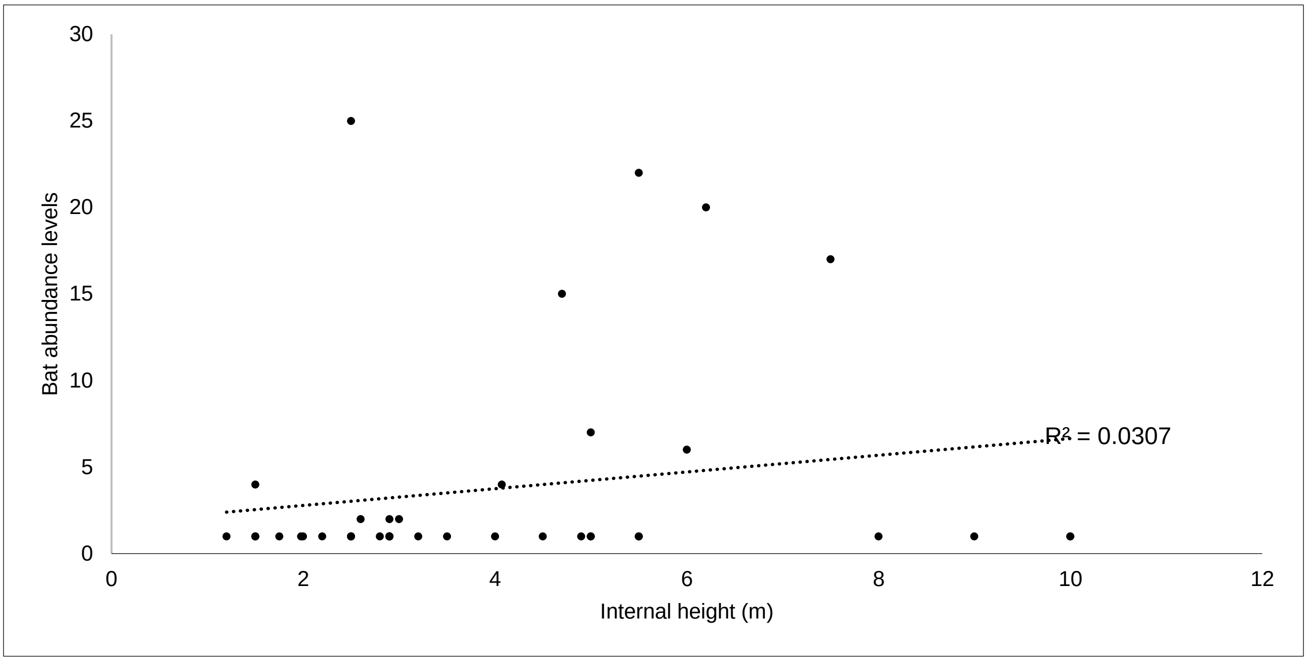



**Figure 4.8**

*Graph showing relationship between internal loft height and bat abundance levels in baseline stage.*

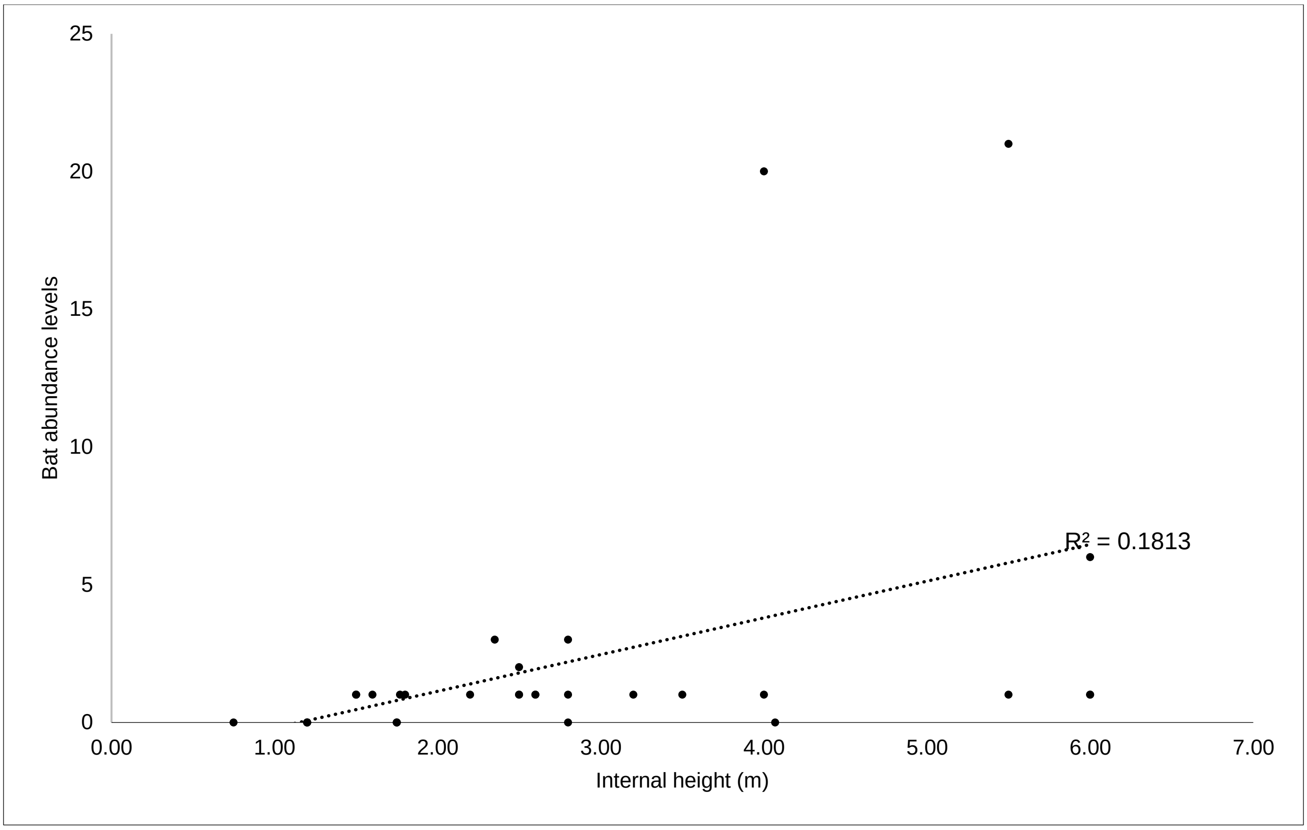



**Figure 4.9.**

*Graph showing relationship between internal loft height and bat abundance levels in modified bat lofts.*

Overall, there was no conclusive evidence to indicate that lofts featuring *P. auritus* and / or *Myotis* spp were significantly larger, taller or warmer compared to those where they were absent. However, these attributes (particularly volume and height) were positively correlated with abundance counts in lofts where presence was already established.

### 4.3.6. Bat houses

Since our dataset was limited to nine 'bat houses', statistical comparisons to other building categories was not feasible. Furthermore, the bat houses themselves were highly diverse with some being built from stone with others from timber. Although roof coverings were primarily made from slate, roof designs varied between flat, pitched and hipped. Although most bat houses were newly constructed, three were adaptations of older structures. Height and surface area were also variable, most houses being relatively small (under 115 $m^2$ in surface area) but two adapted war bunkers exceeded 200 $m^2$. The one distinguishing feature was the absence of human use and these were typically set aside exclusively for roosting bats. The other notable characteristic was that they were typically used to host most new provisions, with 63% (n = 8) of sites using bat houses exclusively for compensation measures (rather than including the compensation measures in a number of different places). Reported costs ranged between £15,000 for smaller 'shed-style' buildings to £125,000 for detached stone structures.

Bat houses are typically associated with being compensation measures for maternity colonies, particularly *P. auritus* and *R. hipposideros*. However, this was only partially reflected in our sample. Although 78% (n = 9) of bat houses acted as compensation measures for *P. auritus* or *R. hipposideros*, only 33% were intended to replace maternity roosts. The remaining bat houses were either intended to compensate for day roosts used by smaller numbers of bats or were provided as enhancements.

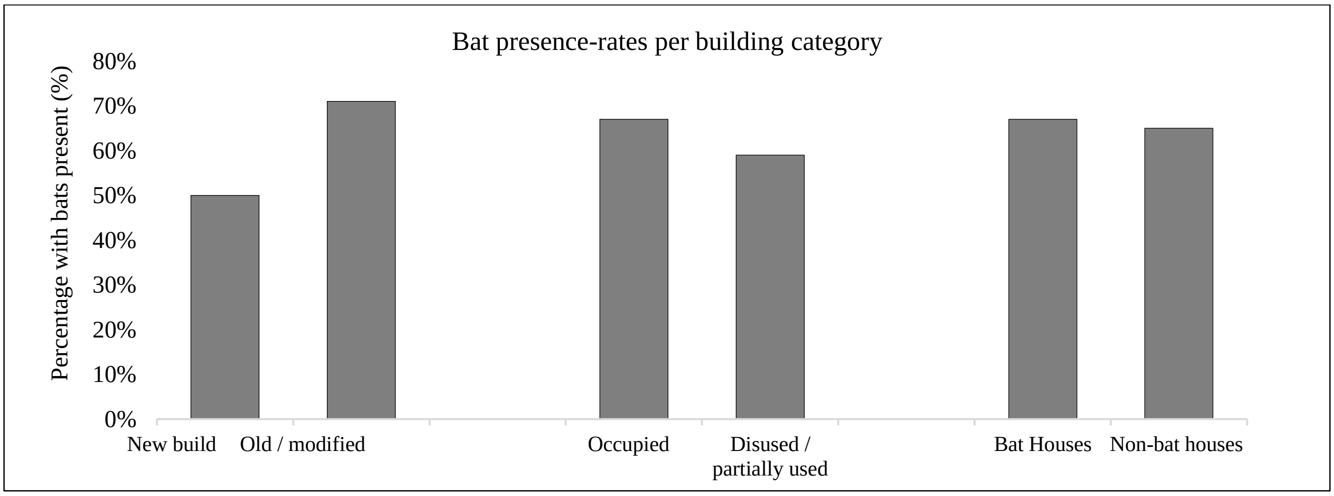
In terms of effectiveness, bat presence was recorded at 78% (n = 9) of bat houses. Although most frequently occupied by *P. auritus* and *R. hipposideros* (five houses each), they were noticeably more effective for *R. hipposideros*. Indeed, the conservation value for *R. hipposideros* increased at four sites because of increased numbers recorded in bat houses during the monitoring period. Two bat houses hosted *R. hipposideros* maternity colonies after being recorded in low numbers during baseline surveys. In contrast, this level of effectiveness was not mirrored for *P. auritus*. Despite being recorded at 56% of bat houses, *P. auritus* counts were generally indicative of lower-level usage ranging from occasional night-roosts (two houses) to small numbers of < 5 bats (three sites). Two of the bat houses acted as compensation for the loss of *P.auritus* maternity roosts, with baseline counts of 13 and 16 at each site. Although both were effective at retaining species presence, post-development *P.auritus* abundance was reduced by 62% and 94% respectively. *P. pipistrellus* was recorded at 33% of bat houses and *P. pygmaeus*, *M. mystacinus* and *B. barbastellus* at one bat house each. However, these latter species were only ever recorded in bat boxes installed externally (*Pipistrellus* spp) or internally (*M. mystacinus* and *B. barbastellus*).

### 4.3.7. Age and Use of Buildings

Figure 4.10 compares the number of active bat roosts and maximum bat counts between buildings of different age categories, intended ecological function and level of human-use.

In terms of building age, bats were recorded in 71% (n = 80) of 'old' retained or modified buildings compared to 50% (n = 32) of 'new' buildings. Retained older buildings were also responsible for consistently higher numbers of bat roosts and maximum bat counts compared to newer builds. There was virtually no distinction between bat houses and non-bat houses (i.e. all other buildings not specifically dedicated for bats) in terms of bat presence or mean roost frequency, although bat houses appeared to be responsible for lower average bat counts compared to other buildings. Although only marginally more effective in terms of bat presence, occupied buildings were nonetheless responsible for consistently higher average bat counts (mean of 10.4) compared to disused buildings (5.6). This may be due to more favourable roosting conditions in terms of warmth or reduced exposure to wind and rain.

It should be noted that *R. hipposideros* presence was excluded from the above assessments. However, when examined in isolation, the GLMM model indicated that this species was significantly associated with disused / partially used buildings rather than occupied ones in our dataset (chi-squared 12.28 with 2 d.f., P=0.003**), in contrast to *Pipistrellus* spp, *P. auritus* or *Myotis* spp.



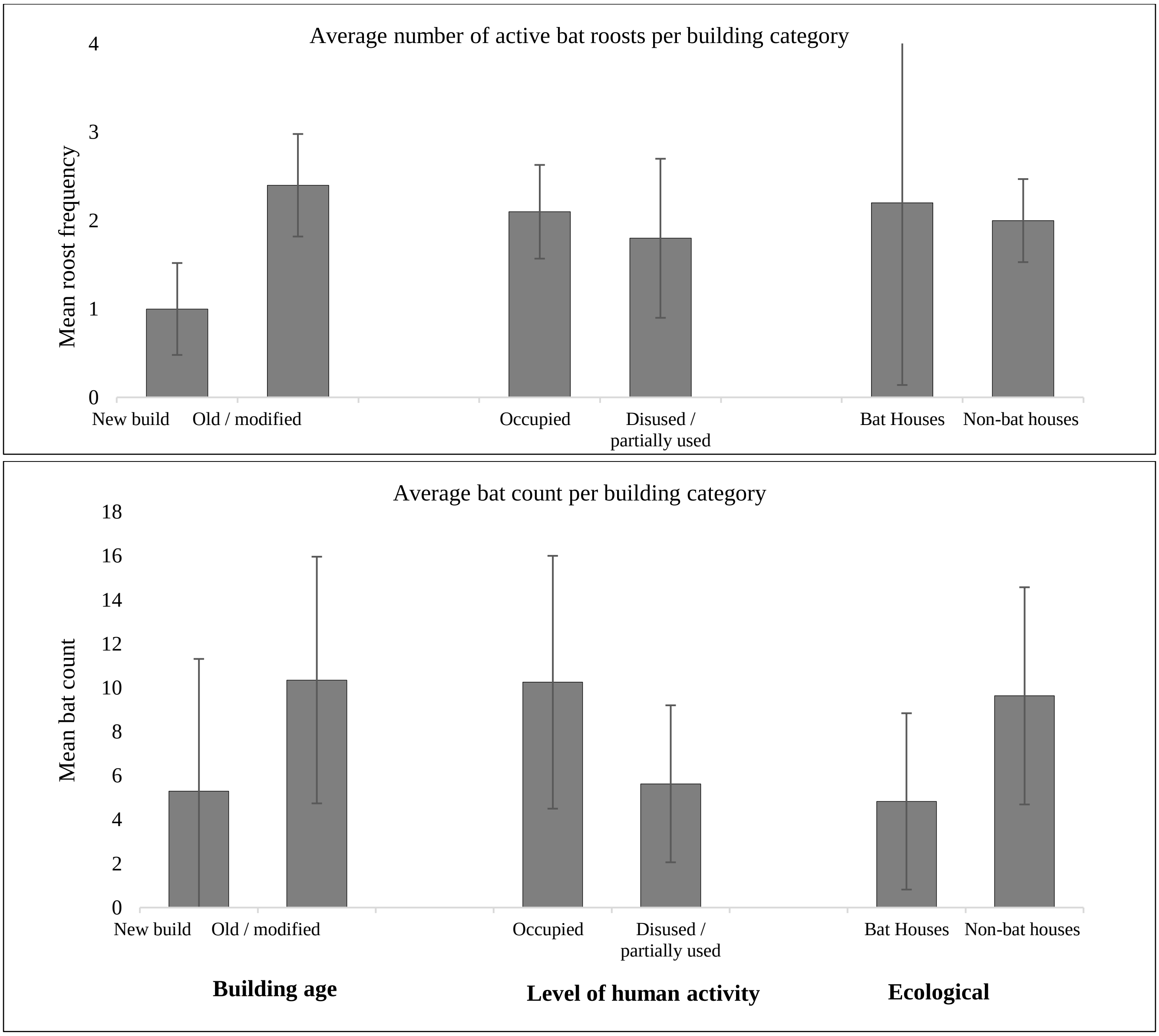



**Figure 4.10.**

*Bat presence rates and average no. bat roosts and bat counts between buildings of different ages, functions and level of human activity*

### 4.3.8. External Cavities

We compared the bat occupancy rates of small external cavity provisions between four different types of host structure: 1) retained or modified buildings; 2) alternative buildings outside of EPS licence activities; 3) new buildings; and 4) trees.

Bats were found to occupy 17% (n = 61) of trees supporting small cavity provisions (i.e. tree-mounted bat boxes). This was a lower occupancy rate compared to new (24%, n = 22), adapted (28%, n = 11) and retained buildings (27%, n = 38). However, the GLMM model reported this difference was not statistically significant (F = 1.29 with 4 and 128 d.f., p = 0.279). The difference was more pronounced when only instances of live bats were considered in the model, with 8% of trees being occupied compared to 17-23% of buildings. However, this was also not quite significant at the 5% level (F = 2.26 with 4 and 98 d.f., p = 0.068).

Differences in live bat abundance counts were also examined using a REML model for the log-transformed data. The model indicated that bat abundance rate differences between host structure types were significant (F = 3.14 with 4 and 20 d.f., p = 0.04*), with higher mean counts recorded at retained / modified buildings (7.9 bats) compared to trees, alternative and new buildings (1.6, 2.4 and 3.8 bats respectively). However, this result should be treated with caution due to the non-normality of the observed and predicted values. Indeed, if the REML model also included instances of bat presence from their signs as well as live bat counts, differences were not statistically significant (F =1.11 with 3 and 9 d.f., p = 0.395).

### 4.3.9. Building Size and Provision Frequency

Correlation analysis was used to determine whether height, surface area and number of roosting provisions were associated with bat roost frequencies and live bat counts. Pearson's product-moment correlation analysis was initially performed to examine the relationship between the above attributes. There was no correlation between building height with either of the outcome variables, with the GLMM model also reporting that height was not a significant factor for bat presence (chi-squared = 1.63 with 1 d.f., p = 0.205). There were small but significant correlations between active bat roost frequency and building surface area (r = 0.19, n = 112, p = 0.05*) as well as the number of new provisions (r = 0.21, n = 112, p = 0.03*). The GLMM model also reported that building surface area was a significant factor for bat presence (chi-squared = 6.71 with 1 d.f., p = 0.011**). However, there was no significant relationship with maximum bat counts for either attribute.

### 4.3.10. Bat Boxes

Bat boxes were the most frequently used roosting provision, being installed at 64% (n = 71) of sites as a compensation or enhancement measures. Box frequencies ranged from 1-41 at sites where they were installed, with an average of 6.6 boxes / site (n = 270).

#### *4.3.10.1. Box-Mounting Locations*

Boxes were broadly classified according to their mounting location as follows: 1) tree-mounted boxes; 2) wall-mounted boxes; and 3) wall-integrated boxes. Wall-mounted boxes could also be external or internal when mounted inside loft voids or outbuildings.

Bats or their signs were recorded in 20% (n = 270) of bat boxes, which was slightly higher than the gross average bat-presence rate when all roost provisions were combined (18%, n = 698). However, there were noticeable differences between the different mounting location groups (Figure 4.11). The GLMM model indicated that the difference in live bat occupancy rates between mounting locations was marginally significant (chi-squared = 10.54 with 3 d.f., p = 0.02*).

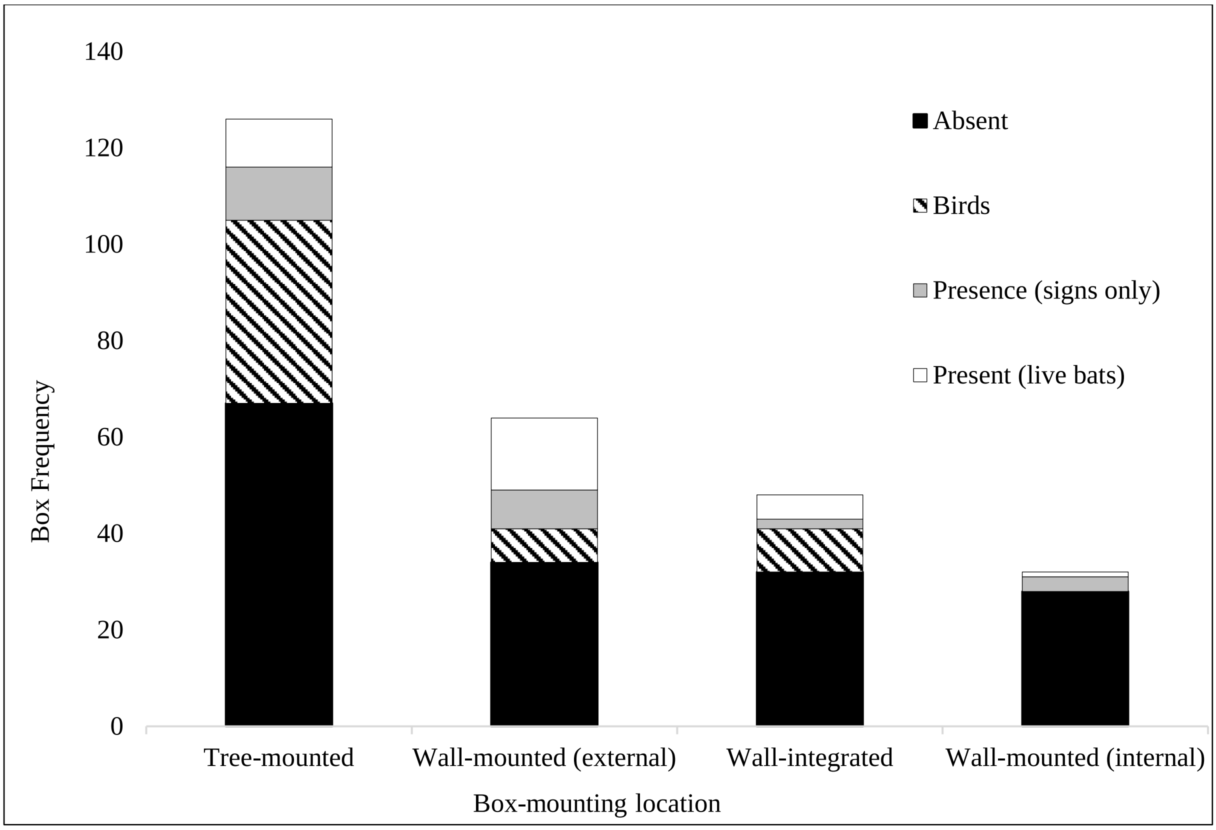



**Figure 4.11**

*Gross bat box occupancy rates*

External wall-mounted boxes featured the highest bat-presence rates (36%, n = 64). Indeed, bat-presence rates for this mounting location were at least double that of the other groups. Tree-mounted, wall-integrated and internally-mounted boxes featured bat presence rates of 17% (n = 126), 15% (n = 48) and 13% (n = 32) respectively. When bat presence was derived from live bats only (as opposed to signs), external wall-mounted box occupancy rates were almost triple that of tree-mounted boxes (23% and 8% respectively). Internally-mounted boxes were the least effective for rates of both bat presence and live bat occupation (13% and 3% respectively).

Nesting / roosting birds or their signs were recorded in 30% (n = 126) of tree-mounted boxes – almost triple that of wall-mounted boxes (11%, n = 64). No signs of bird activity were recorded in any of the internally-mounted boxes.

REML analysis of log-transformed bat counts also indicated that differences between box mounting locations were significant (F = 4.84 with 3 and 133 d.f., p = 0.003**). This was due to a relatively high average count of 11.3 bats in occupied wall-mounted boxes. However, this was almost exclusively due to a large *P.pygmaeus* maternity colony using three boxes all cited within 5 m of each other at the same site. Since this was the only occasion where > 6 bats were recorded using bat boxes, these records were considered outliers since they did not represent other occupied boxes where bat counts were < 5 in 87% (n = 31) of cases.

Average bat box heights above ground level were 4.6m, with tree-mounted boxes being slightly lower at 3.8m and wall-mounted / integrated boxes slightly higher at 5.4m. The lowest occupied box was recorded at 1.8m and the highest at 11m. However, fitting height in mixed models indicated that it did not have a significant impact on either bat presence (F = 0.31 with 1 and 128 d.f., p = 0.577), or on counts (F = 0.02 with 1 and 232 d.f., p = 0.894). Likewise, there were no significant differences between boxes on different orientations (north, north-east etc., $\chi 2$ = 4.69 with 8 d.f., p = 0.790 for presence, F = 1.56 with 8 and 237 d.f., p = 0.139 for counts). There was insufficient bat count data to assess the relationship between bat counts and orientation using this method.

*4.3.10.2. Bat Box Models*

Box volume varied between 900 cm$^3$ for small timber-style boxes, to volumes in excess of 30,000 cm$^3$ for large heated boxes and bespoke designs integrated into the eaves. Overall, the average volume was 5,148 cm$^3$ and comparable to that of the Schwegler 1FQ model. However, when internal volume was plotted against maximum bat counts, Pearson's product-moment analysis indicated there was no correlation between the two variables ($r = 0.02$, $n = 254$, $p = 0.81$).

Nineteen bat box model designs were represented in our dataset, with occupancy rates per model included in Table 4.7. The Schwegler 1FF, 2F, 1FR/2FR and 2FN models were installed most frequently and accounted for 54% (n = 270) of boxes. 72% of boxes were primarily constructed from woodcrete, although certain models (e.g. the 1FF and 1FQ) also featured timber or chipboard in the internal layout. Only 20% of boxes were primarily made from timber including models such as the Wildcare and Kent bat boxes, several bespoke boxes and those with a heating included. Clay and concrete boxes accounted for 8% and primarily included integrated box models.

**Table 4.7**

*Occupancy rates of the most frequent bat boxes recorded during this project*
*See appendix 3 for model details)*

| Box Model | Occupancy Rates | | | |
|---|---|---|---|---|
| | Bat presence | Live bats | Birds | Mean no. bats |
| 1FF (n=53) | 17 (32%) | 8 (15%) | 4 (8%) | 2.75 |
| 2F (n=43) | 10 (23%) | 5 (12%) | 11 (26%) | 1.2 |
| 1FR / 2FR (n=32) | 8 (25%) | 8 (25%) | 7 (22%) | 1.1 |
| Timber - other (n=26) | 0 (0%) | N/A | 6 (23%) | N/A |
| 2FN (n=-19) | 2 (11%) | 2 (11%) | 11 (58%) | 3.5 |
| 1FW (n=13) | 0 (0%) | N/A | 5 (38%) | N/A |
| 1FD (n=11) | 6 (55%) | 3 (27%) | 0 (0%) | 1 |
| Ibstock bat brick (n=10) | 0 (0%) | N/A | 0 (0%) | N/A |
| 1FQ (n=7) | 2 (29%) | 0 (0%) | 1 (14%) | N/A |
| Kent Bat Box (n=6) | 1 (17%) | 1 (17%) | 0 (0%) | 1 |
| 1FS (n=6) | 2 (33%) | 1 (17%) | 4 (67%) | 1 |
| Habibat (n=4) | 0 (0%) | N/A | 2 (50%) | N/A |
| American style (n=3) | 3 (100%) | 3 (100%) | 0 (0%) | 47.7 |

In terms of the four most popular models, the 1FF was responsible for the highest bat presence rates for bats and lowest for birds. In contrast to the 2F and 2FN (which were exclusively mounted on trees), 34% of the 1FF boxes were mounted on external walls, 32% on internal walls and 34% were hung on trees. Interestingly, the bat presence rates for external wall-mounted 1FF boxes was 72% (n = 18) compared to 18% for internally-mounted boxes (n = 17) and 6% for tree-mounted boxes (n = 18). In the study by Swift (2004), flat box designs like the Schwegler 1FF demonstrated improved thermal stability over cubic or cylindrical boxes like the 2F, 2FN and 1FD because of a higher surface area-to-volume ratio.

The tree-mounted 2F and wall-integrated 1FR/2FR models both demonstrated similar bat presence rates of 23% (n = 43) and 25% (n = 32) respectively. However, occupancy rates for live bats in the 1FR / 2FR model was double that of the 2F

(25% and 12% respectively). Apart from the 1FR / 2FR boxes, the only other examples of integrated box designs were the Ibstock bat brick, where ten boxes were installed at a single site, and Habibat boxes where two boxes were installed at two sites. However, no bats were recorded in these models.

The 2FN tree-mounted model featured the lowest bat presence rate of the four most popular models. This design also featured the highest rate for bird presence. Bat box monitoring schemes have attempted to reduce nesting bird competition by installing additional bird nest boxes adjacent to bat boxes, although with only limited success (Meddings *et al.* 2011; Dodds and Bilston, 2013). Other models with noticeably high rates for bird presence were the large woodcrete 1FW hibernation box and 1FS large colony box.

Although other tree and wall-mounted woodcrete models were variable in terms of bat presence, they were installed too infrequently or at too few sites to reliably assess their effectiveness. However, the 1FD was notable because it was effective at all three sites where it was installed, had a noticeably high bat presence rate and no instances of bird presence.

Apart from the Kent Bat Box where a single bat was recorded in one of the boxes, bats were absent in all other small timber boxes. Indeed, the GLMM model reported that bat presence rates varied according to box material, with bat presence-rates for timber boxes being significantly less than woodcrete models (chi-squared=6.78 with 2 d.f., p = 0.03*). However, overall presence rates between different woodcrete models was not significant, and this may be attributed to the low sample sizes for individual models.

In terms of heated bat boxes, only five were surveyed during this project. However, no bats or evidence of use was recorded in any of the boxes. Despite examining the structures in detail and questioning site personnel, it was generally not possible to confirm whether the heating elements were functioning at the time of the survey. Although two of the boxes featured unlit LEDs, this may have simply indicated the thermostats had not been triggered during the warm conditions the survey work was typically carried out.

The most effective stand-alone box was a bespoke timber, un-heated model based on the American-style bat house (Tuttle *et al.* 2013) where 100% of boxes (n = 3) were occupied with an average of 48 bats/box. This was the only model to feature > 6 bats at any one time. This box superficially resembled the 1FF, also being flat-fronted, although its increased size, sealed joints and presence of two smaller 15-20mm internal compartments would have provided a larger surface area-to-volume ratio and wider range of internal microclimates. However, this model was only installed at a single site and on a single building immediately following the exclusion of a *P.pygmaeus* maternity colony directly behind one of the boxes. Therefore, despite proving itself to be highly effective in this instance, this was a singular scenario unique to this site and not representative of other mitigation schemes where boxes were generally installed alongside other provision types, located away from the removed roosts or installed some time before or after exclusion. Furthermore, the small sample size and absence of other box models at this site prevented a reliable assessment of its relative effectiveness.

It was notable that bird signs were absent in all box designs where access point apertures were 17mm or under. Similarly, box models with the highest bird presence rates featured access apertures at least 25mm wide. Although the 2FN model had a relatively high bird occupancy rate, it was not clear whether birds were primarily using the narrower 20mm access point at the front of the box or the wider aperture at the base.

### 4.3.11. Access points

#### *4.3.11.1. Access point frequencies*

The relationship between bat occupancy rates, maximum bat counts and the total number of new access points entering into loft voids, wall tops and ridge voids was examined. However, following analysis using linear and quadratic regression as well as REML modelling, there was no clear correlation or significant relationship between the variables for any of the three roost sub-groups.

After BCT's own monitoring data was combined with that collected by ecological consultants, 125 access points were confirmed as being actively 'in-use' during post-development monitoring surveys. When considering only these roosts, bats accessed 94% (n = 114) of these structures via a single access point.

Only 6% of roosts featured 2-3 'active' access points and no provisions featured more than this. Similarly, surveyors only recorded single 'active' access points into new bat lofts during the monitoring period, despite more being available. In contrast, 6% (n = 128) of occupied new provisions were accessed by multiple bat species via single access points. Therefore, there were more instances of multiple bat species using the same access points than single species using multiple access points.

#### *4.3.11.2. Access point use rates*

Overall, the average use-rate for new access points was 8% (n = 1,629). External access points had a significantly higher use-rate (8%, n = 1,209) compared to internal ones (4%, n = 420) and this was confirmed by the GLMM model (chi-squared = 8.69 with 1 d.f., p = 0.003**). Both rates were noticeably lower than the equivalent gross average rate for roost-occupancy (18%, n = 698). This was partly because many roosts featured more than one potential access point, but also because bats were recorded using numerous roosts where the point of access was 'unknown' or ambiguous.

Use-rates for the most frequently installed access point sub-groups were directly compared. The GLMM model once again confirmed that use-rates varied considerably between sub-groups and differences were highly significant (chi-squared = 37.20 with 8 d.f., p < 0.001***). When examining external access points in isolation, apertures leading into bat boxes had the highest use-rate (20%, n = 232) followed by those leading into wall tops (11%, n = 351). Other external access points with lower use-rates were those at the bases of boarding and panels (7%, n = 70), and ridge tile access (4%, n = 162). The least effective access points were stonework gaps (1%, n = 94) and bat tiles (0%, n = 45).

For internal access points, those leading into bat boxes (18%, n = 28), boarding / panels (5%, n = 120) and internal wall tops (50%, n = 2) also had the highest use-rates, although noticeably less than the external equivalents.

Since many of these access points were inseparable from the roost structures themselves (for example, bat boxes and gaps in stonework), we isolated access points leading into void-type roosts (i.e. bat lofts, bat houses and outbuildings).
When void access points were examined in isolation, only 22 were recorded as 'in-use' during post-development monitoring surveys. Larger openings exclusively used by *R. hipposideros* accounted for 14% (n = 22) of these access points. The remaining 86% were apertures leading into modified or retained voids with none leading into new structures. Just over half of these (57%, n = 19) were retained or slightly modified apertures. The smaller number of new or non-intended access points (43%, n = 19) were primarily larger openings used by both *R. hipposideros* and *P. auritus*. For *P.auritus*, these larger openings may have been used for indirectly accessing internal cavities inside the voids. The most frequently used direct access points for *P. auritus* were wall top apertures at the eaves, gaps behind cladding and ridge tiles.

#### *4.3.11.3. Aperture widths*

Figure 4.12 displays the aperture widths for all confirmed access points during post-development monitoring surveys. The GLMM model indicated there was a highly significant quadratic relationship between bat species and aperture width (chi-squared = 34.22 with 1 d.f., p < 0.001*** for the quadratic term). Indeed, when new provisions were examined alongside non-intended access points, 84% were < 30mm (n = 204). For the remaining 16% of active access points > 30mm (n = 32), these were largely used by *P. auritus*. However, 56% of these were classified as 'indirect' openings leading into intermediary voids (for example, open windows and doorways) rather than directly into the host roosting structures themselves. Figure 4.13 shows how there was a noticeable reduction in access point use-rates from 7% (n = 1717) to 4% when aperture widths increased beyond 26mm (n = 565).

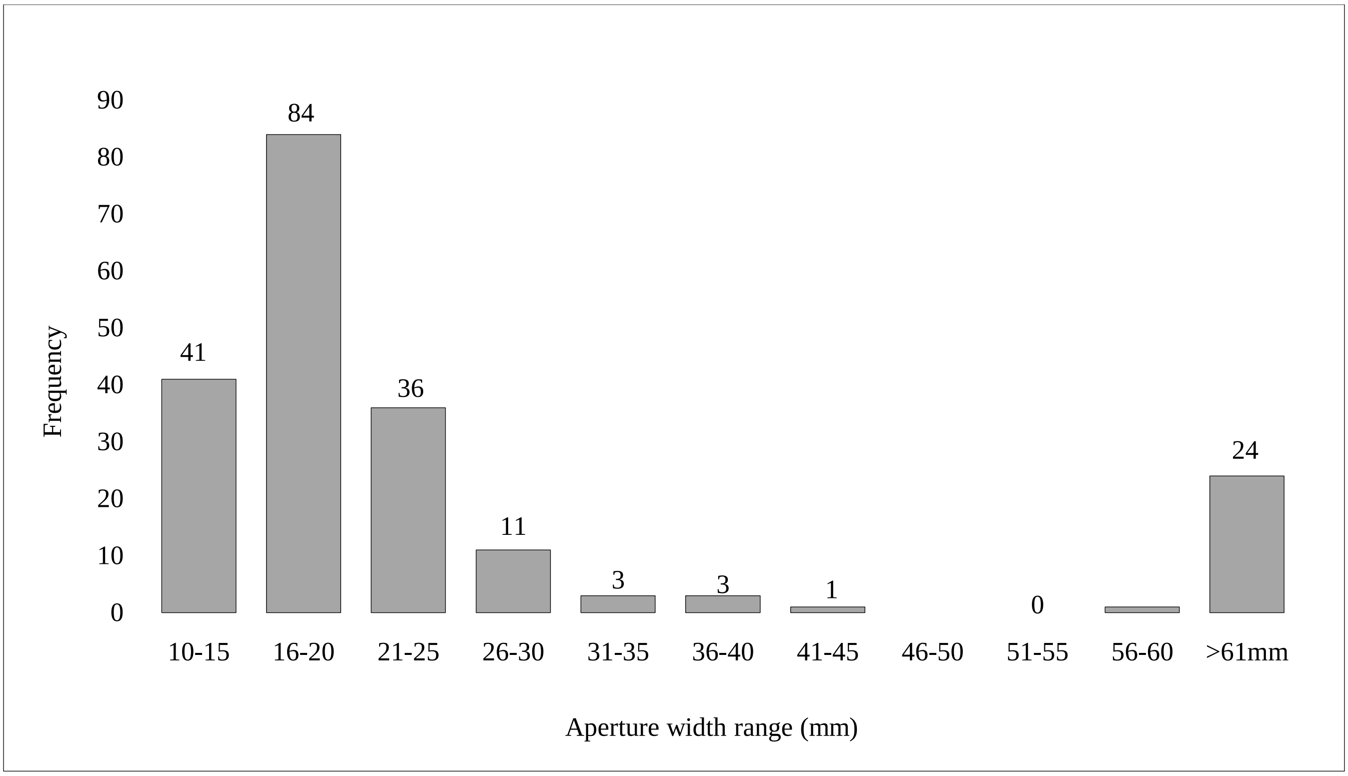



**Figure 4.12**

*Frequency of access points with different widths*

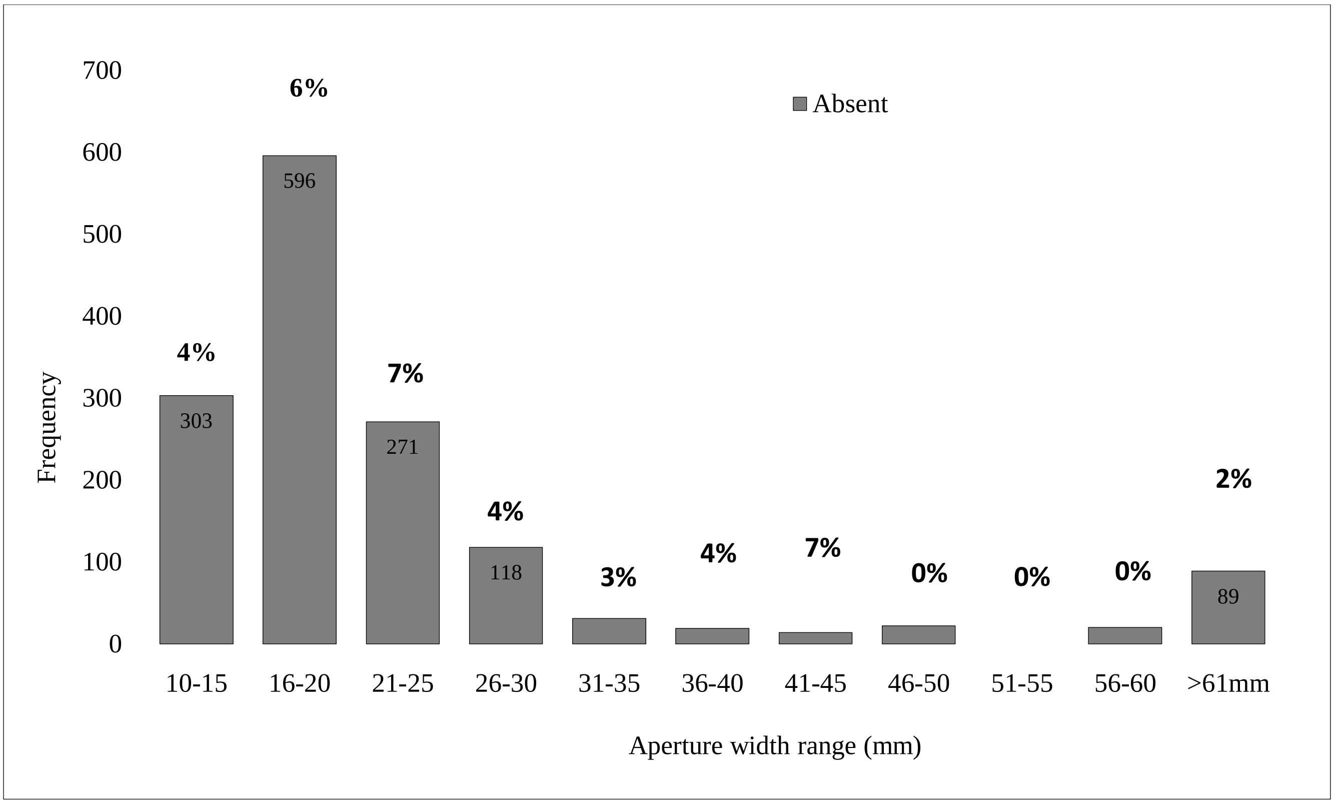



**Figure 4.13**

*Use-rates of new access points with different widths*

When active access points within the 10-35 mm range were examined in more detail (Figures 4.10 and 4.11), the most frequently used for all species were those with apertures of 13-22mm (84%, n = 143).

*4.3.11.4. Access point height*

Figure 4.14 displays the height above ground-level (m) for access points assessed during BCT's monitoring surveys. The GLMM model indicated a significant quadratic relationship with bat presence (chi-squared = 7.43 with 1 d.f., $p < 0.006$**), but presence-rates generally only increased up to approximately 3-4m. Presence-rates appeared to reduce for access points above 6m, although this was not significant and may be explained by a slightly reduced ability of surveyors to detect bats accessing apertures this high.

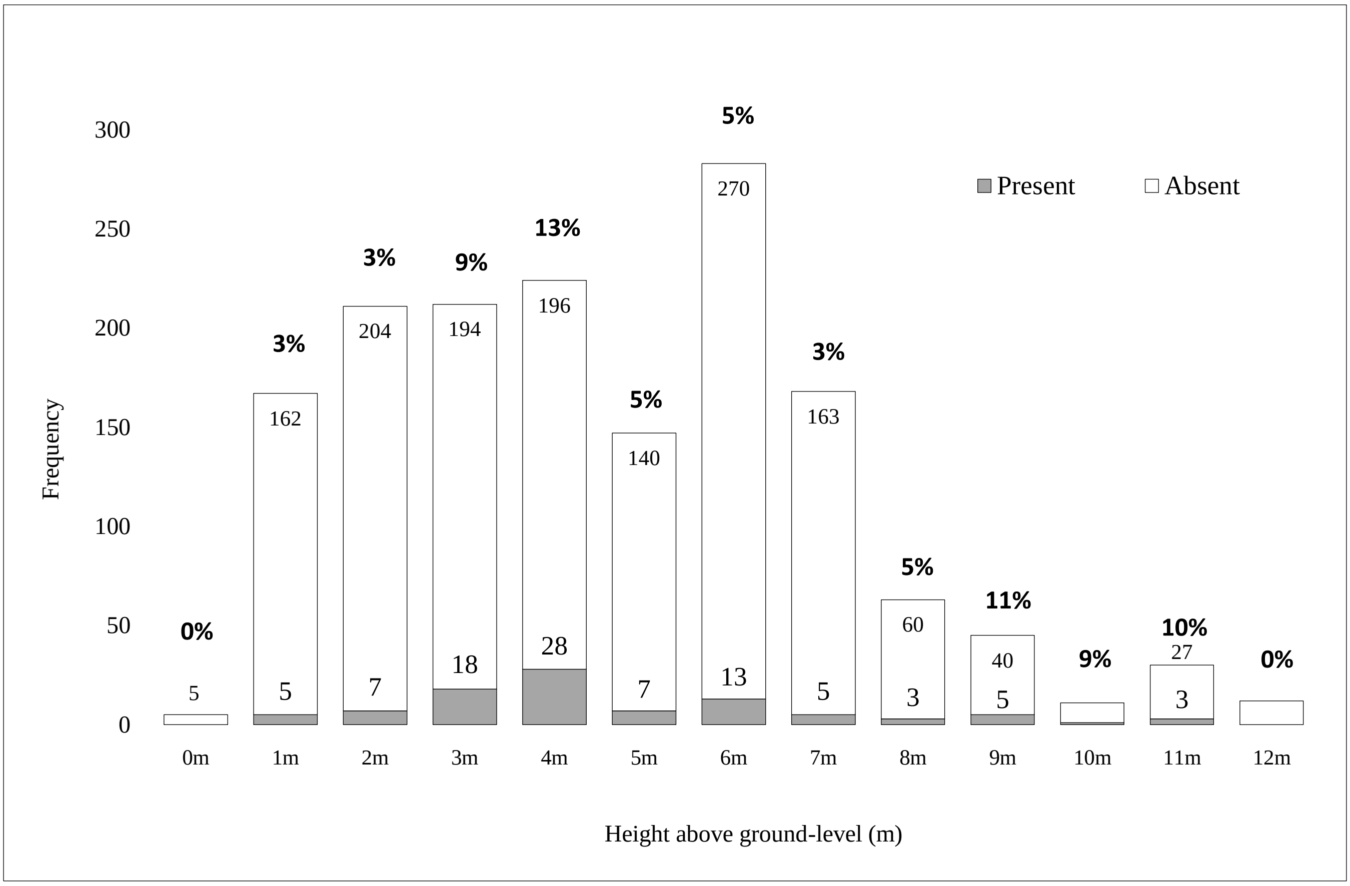



**Figure 4.14**

*Use-rates of new access points per height above ground-level*

*4.3.11.5 Overhangs and corners*

It was observed that 47% of confirmed access points during both the baseline and monitoring stages (n = 401) were located directly adjacent to some form of corner or overhang at 90° to the opening. When new access point provisions were examined in isolation (excluding bat box access points), it was also recorded that openings adjacent to overhangs or corners were twice as effective (bat-use rates of 8%, n = 571) compared to those that were more exposed (3%, n = 723). The GLMM also indicated that this relationship varied significantly between species ($\chi^2 = 12.34$ with 3 d.f., $p = 0.006$**), being more evident for soprano pipistrelle and brown long-eared bats compared to common pipistrelle and Myotis spp.

#### *4.3.11.6 Comparisons with baseline and non-intended access points*

Use-rates for the new access point groups and sub-groups were compared to the 363 baseline and non-intended access points. Similar to roosting provisions, the frequency of baseline and non-intended access points were approximately three times larger than newly-installed access points. 95% (n = 363) of all baseline and non-intended access points were external. In contrast, only 5% of confirmed access points were internal. The most frequent external access points were wall top gaps (31%, n = 343), followed by stonework gaps (18%) and ridge tiles (9%). Despite accounting for a low proportion of access points as a whole, internal wall top crevices were the most frequently confirmed internal access point leading into internal cavities or other voids.

In terms of species composition, *Pipistrellus* spp use-rates for wall tops, roof tiles (except ridge tiles) and stonework gaps were consistently above the gross average of 72% (n = 363) compared to other access point sub-groups. Likewise, internal wall tops were used exclusively by *P. auritus* in our sample. *P. auritus* use-rates for larger external openings were also noticeably higher than the gross average, predominantly because these were mostly indirect openings like open windows and doorways leading into voids or small internal cavities. Although *Myotis* spp were recorded using only 9% of confirmed access points, this species used a noticeably higher proportion of hip, edge and ridge tiles compared to other access point sub-groups.

When discounting bat box access points, wall top gaps were responsible for both the largest proportion of baseline / non-intended (31%, n = 362) and 'active' newly-installed access points (34%, n = 116). In contrast, despite being the second most frequent baseline and non-intended access point sub-group (18%, n = 362), new gaps in stonework and brickwork accounted for a very low proportion of effective access points (0.9%, n = 116).

A conspicuous trait in the dataset was that access points were not recorded or confirmed for 39% (n = 480) of all baseline and non-intended roosts. However, the rate of unknown / ambiguous access points was noticeably different between species and roost structure groups. For example, access points were not recorded for 11% (n = 158) of baseline and non-intended *P. pipistrellus* roosts and 14% (n = 87) of *P. pygmaeus* roosts. However, the rate for unknown access points was over three times higher for *P. auritus* (48%, n = 94) and *Myotis* spp (48%, n = 52). This was particularly pronounced for access points leading into small internal cavity roosts which were unknown for 81% (n = 21) of *Myotis* spp and 64% (n = 22) of *P. auritus* roosts.

## 4.4. Discussion

Our data was consistent with previous studies regarding the importance of prioritising roost retention or modification over removal and compensation (Briggs, 2004; Mering and Chambers, 2014; Mackintosh, 2016; Voigt *et al.* 2016; Lintott and Matthews, 2018). It appears more likely that existing roosts will be preferentially selected over new ones (Zeale *et al.* 2016). There may be a perception amongst certain stakeholders that compensation measures that have been approved by the EPS licensing process will always be fit-for-purpose. Although there were large differences between species and provision-types, the average occupancy rate for new roosting provisions in this project was only 18%. It is important not to draw conclusions about the wider implications such effectiveness may have on bat species without more information. However, such low levels of use are unlikely to meet the expectation of many practitioners, decision-makers and roost owners.

We do not currently understand why bats do not readily occupy new provisions (Voigt *et al.* 2016), at least to the degree anticipated in mitigation strategies. It is generally accepted that surrounding habitat quality is likely to be a key factor determining the effectiveness of new provisions (Lintott and Matthews, 2018; Mackintosh, 2016; Bilston, 2014). Yet, findings from this project revealed relatively low occupancy rates despite the vast majority of sites being located adjacent to apparently excellent foraging and commuting habitat. Furthermore, we rarely recorded any evidence of noticeable habitat losses or degradations since the baseline stage. Nonetheless, there are likely to be a complex array of ecological, environmental and temporal factors operating outside site boundaries, and therefore beyond the control of those involved in site-based mitigation schemes, that also influence provision effectiveness.

The fact that this project and other mitigation studies have generally reached the same conclusion suggests that the selection and design of new provisions in this study may have had less of an effect on target bat presence and abundance levels than the initial decision to retain, modify or remove the original roost. This may be related to how bats find and start using roosts. Ripperger *et al.* (2019) tracked *Nyctalus noctula* associations during roost switching behaviour, reporting that information transfer probably occurs by adult bats guiding juveniles to new roosts. Indeed, bats are known to use a highly specialised system of shape detection, learning, memory and information transfer for decreasing the costs involved in finding new structures (Dietz *et al.* 2009; Ruczyński and Bartoń, 2012). Using modelling simulations for woodland bats, Ruczyński and Bartoń (2012) predicted that bats may be able to find new tree cavities quickly, but only if they had already learned to discriminate particular tree shapes and associate them with suitable roosts. Furthermore, since their echolocation primarily functions at a short range, it may take bats a long time to find new roosts (Moller *et al.* 2016).

Evidence suggests that factors such as provision frequency and size of the local bat assemblage may be possible predictors of effectiveness (Meddings *et al.* 2011; Mering and Chambers, 2014; Lintott and Matthews, 2018). Indeed, our own findings somewhat support this view by indicating a small relationship between the number of active bat roosts at buildings with the number of newly-installed provisions. However, this relationship was only marginally significant and our analysis revealed no clear relationship between bat occupancy rates and number of access points. Furthermore, our examination of bat activity levels also indicated that high levels of bat activity on site was not necessarily associated with large numbers of roosting bats. The premise that bat occupancy rates increase with bat abundance and provision frequencies is both logical and intuitive. However, it also assumes that new roost colonisation is a somewhat passive process and so may not conform to the highly complex behaviours exhibited by bats when searching for and using new roosts (Dietz *et al.* 2009; Ruczyński and Bartoń, 2012; Ripperger *et al.* 2019). It was also considered notable that the presence of bats in small cavities was determined by live bats (as opposed to signs only) far more frequently compared to bat lofts. Although this is likely to be at least somewhat related to the difficulties involved in detecting live bats within highly complex structures like loft voids, this also suggests we may be underestimating or undervaluing the effectiveness of other small cavity roosts integrated into buildings (for example, ridge voids or wall tops), simply because they typically cannot be searched exhaustively for evidence that accumulates over time like bat lofts and mounted bat boxes.

Consistent with this project, previous studies (Waring, 2011; Lintott and Matthews, 2018) also noted that bats had been recorded using parts of buildings not explicitly intended as mitigation. Although 29% (n = 210) of active roosts recorded during BCT's monitoring work related to non-intended provisions, our assessment also demonstrated that such roosting structures did not make a notable contribution to the overall effectiveness of higher impact schemes. However, they clearly resulted in a modest number of lower-status schemes retaining the presence and abundance levels of target species, particularly *Pipistrellus* spp.

Our analysis indicated that bats were not simply using new provisions at random and there were significant differences between different types of roost and access points in terms of occupancy rates. It was also apparent that different bat species displayed distinct preferences for certain provisions over others. This is considered a positive outcome because it indicates that, despite the undeniable importance of other factors, ecological practitioners and decision-makers can still influence scheme effectiveness by way of roost design selection, positioning and application.

The results of this project appeared to display a common theme whereby bats were generally more likely to occupy structures that most closely resembled what was removed. This was most clearly exhibited by the significant differences displayed by *P. auritus* bats re-occupying modified roof voids compared to new bat lofts. However, this was also demonstrated by the increased use of retained or modified access points compared to newly-installed ones, the significantly higher occupancy rates of new provisions installed on retained rather than new buildings, and the significantly increased use of flat-fronted wall-mounted bat boxes over cubic tree-mounted ones. Regarding this last point, this project exclusively targeted case studies which affected roosts within buildings instead of trees. Therefore, despite cubic tree-mounted bat boxes being highly effective in certain scenarios, they were originally designed to mimic tree cavities and this may explain their reduced level of use in this project compared to flat-fronted wall mounted bat boxes which are more likely to effectively mimic building roosts (see Appendix 3). Furthermore, wall top crevices were the most consistently effective provision and particularly so for *Pipistrellus* spp. These included roosts accessed by gaps at the eaves, under fascia panels, bargeboards and apexes of gable ends where there was no evidence to indicate that bats may be roosting elsewhere in the roof. Provisions like this were typically very similar in form and function to what was removed or present in the locality. This would also help explain the pronounced variability in provision effectiveness between sites in this project and other studies (Moller *et al.* 2016), with the same provisions exhibiting different occupancy rates at sites with the same species.

BCT's results reinforce the mitigation hierarchy (Mitchell-Jones, 2004). It is acknowledged that integrating retained bat roosts into new developments will not always be a feasible option. However, it is important that there is a genuine awareness amongst stakeholders that mitigation schemes based around roost removal and compensation may have highly reduced levels of efficacy compared to those based around modification or retention. This was particularly evident for *P.auritus* schemes in this project. Ultimately, bat roosts must only be removed as a last resort and not driven by the assumption that a new compensation roost may be preferable to bats compared to retaining the original. Where roost retention / modification is an option, it may also directly benefit stakeholders by reducing project costs and possible negative attitudes caused by ineffective measures (Mackintosh, 2016).

### 4.4.1. Bat Lofts

Although Stone *et al* (2013) reported that bats used 74% of bat lofts, the available monitoring data prevented the study from assessing abundance counts. Assuming that roost retention is not possible, new bat lofts in new or modified builds are generally perceived as being the most effective compensation measures if like-for-like recreation of the original roost is not feasible (Stone *et al.* 2013; Mackintosh, 2016). Indeed, a large proportion of English Nature's guidelines are dedicated to bat loft creation and enhancement measures (Mitchell-Jones, 2004).

Consistent with previous findings (Lintott and Mathews 2018) and widely held perceptions as a whole, *P. auritus* were recorded in bat lofts far more frequently compared to other species. Yet project findings also reflected those of Mackintosh (2016) where surveyors only recorded signs of low-level use, despite the structures themselves being positioned near optimal habitat and constructed from similar materials to roosts that were removed. Similarly, Briggs (2004) assessed the effectiveness of numerous bat lofts but reported that none effectively compensated for the *P. auritus* roosts that had been removed despite their volume and height meeting standard requirements.

Although loft volume and height were positively correlated with abundance counts where *P. auritus* presence had been recorded at the baseline stage, we recorded no significant evidence to indicate that such bat lofts were significantly larger, taller or warmer compared to those where they were absent. Such findings indicate that even new loft voids with comparable volumes and temperatures to modified ones failed to attract bats or comparable abundance levels of bats in almost all cases. Of course, this may be because the attributes attracting *P. auritus* to loft voids are too subtle to have been detected by the measures used in this project. However, it may also be that the presence of bats in new loft voids is not directly determined by the structural components we typically incorporate into these structures. The possibility that the newness of the materials used and their smell may play a part; this requires further research.

It was also notable that the occupancy rates for bat presence in modified lofts was relatively comparable to that demonstrated in the new loft conversions of adapted buildings. This demonstrates that bat(s) were at least aware of these new bat lofts in building conversions and accessed them at some point, but had not used them for more regular or higher-status roost occupancy, perhaps because of the internal roosting conditions. The fact that bat presence was never established in new bat lofts that had been incorporated into newly-built structures suggests that bats may not have found or used the void at all, so may be more related to its location and nature of the access points than the internal roosting conditions.

### 4.4.2. Bat Houses

The purpose of bat houses is to introduce new roosting space into development schemes when natural roost retention or compensation within the modified structures is not possible (Mackintosh, 2016). It may also be possible to position this roosting space adjacent to higher quality habitat or lower artificial-light levels compared to the original or proposed build. However, although they may structurally resemble other buildings with roosting bats, our results did not indicate that bat houses featured increased rates of bat presence, roost numbers or bat abundance levels compared to regular domestic buildings. Indeed, occupied buildings typically featured higher roost and bat abundance in BCT's study compared to disused buildings. This may be related to the higher temperatures of occupied buildings or a more diverse array of potential roosting features. The notable exception to this related to *R. hipposideros*, which was clearly using disused buildings in our sample and was responsible for the effectiveness of several bat houses.

It is acknowledged that this project only assessed a small sample of bat houses and they have been demonstrated to be highly effective in some mitigation schemes even for *P. auritus* maternity colonies (Garland *et al.* 2017). Furthermore, our sample predominantly featured mitigation schemes based around domestic and commercial building developments so bat houses may represent a highly effective alternative to bat boxes for road and engineering schemes where buildings are absent and provisions can be set back from human disturbance. However, considering that bat houses were by far the most expensive type of provision used in mitigation schemes for this project, their application in schemes where alternative buildings are available is questionable and should be carefully considered during the project planning stages. Bat houses may be selected if roost owners are concerned about bat presence in occupied buildings, particularly if they are concerned about health risks (Lourenco and Palmeirim, 2004; Flaquer *et al* 2006) or conflicts with future developments. However, in such situations, constructing a bat house may be less preferable (and costly) compared to more directly addressing any misunderstandings, prejudice or ignorance about bats (Battersby, 2010) or solutions to future development conflicts

### 4.4.3. Bat Boxes

Whilst several long-term studies have examined roost uptake in bat boxes (Tuttle *et al* 2013; Poulton, 2006; Flaquer *et al.* 2006), there is clearly a difference in the application of bat boxes between habitat enhancement and compensation measures for offsetting roost removal. Our project findings were comparable to that of (Aughney, 2008) where bat occupancy rates were 20-30% with presence typically being assigned by signs only or by less than 5 bats.

In terms of the four most frequently used models in this study (Schwegler 1FF, 2F, 1FR/2FR and 2FN), the flat-fronted 1FF showed both the highest bat presence rates and also the lowest bird occupancy rates. More generally, bats were present more frequently in external wall-mounted boxes compared to tree-mounted and wall-integrated boxes. Internally-mounted boxes were the least effective. Bat occupancy rates for wall-mounted 1FF boxes were also considerably higher than those mounted internally or on trees. In contrast, nesting or roosting birds were recorded in tree-mounted boxes far more regularly than wall-mounted boxes. However, it is important that such results are not taken out of context because occupancy rates in general were highly variable and site-specific. Furthermore, despite bat boxes being the most frequent new roosting provision in our dataset, the sample size was still relatively small. Indeed, most bat box models were used too infrequently to draw any meaningful conclusions regarding their effectiveness.

Of course, the higher occupancy rates of wall-mounted boxes may also be related to temperature, with boxes in these locations more likely to be directly exposed to sunlight and less buffered by woodland (Tuttle *et al.* 2013). This was also demonstrated by Dodds and Bilston (2013) and Bilston (2014) when bat box temperature sensors in recently coppiced woodland exhibited larger temperature fluctuations compared to those in shaded boxes.

Swift (2004) demonstrated that certain bat box models were variable in terms of insulation and thermal stability. However, rather than the material used in bat box construction, this study demonstrated that thermal stability differences were more attributed to bat box size and the degree to which removable panels and lids allowed warm air to escape. In terms of shape, flat box designs like the Schwegler 1FF demonstrated improved thermal stability over cubic or cylindrical boxes like the 2F, 2FN and 1FD because of a higher surface area-to-volume ratio.

The fact that integrated bat boxes were less effective than other small external cavity structures on new builds (for example, ridge voids, wall tops or timber cladding) may suggest that either current designs are not optimal, or that even optimal designs are simply not as preferable to bats compared to other integrated structures.

Although woodland-based bat box schemes and studies like Dodds and Bilston (2013) have reported cylindrical woodcrete models (for example, the Schwegler 1FS and 2FN) boxes to be more effective than the 1FF, Poulton (2006) also reported the Schwegler 1FF to feature significantly higher bat occupancy rates compared to the 2FN, 1FS and 2F models, particularly for *Pipistrellus* spp. The larger version of the 1FF (the 1FFH) was also the only effective model reported by Mackintosh (2016).

The most effective stand-alone box in this study was the bespoke timber, flat-fronted model based on the American-style bat house (Tuttle *et al.* 2013) where all boxes were occupied by a maternity colony of *P. pygmaeus*. This was also considered the most similar alternative model to the 1FF recorded during this project, although its increased size, sealed joints and multiple compartments would have provided a larger surface area-to-volume ratio and wider range of internal microclimates.

Such design measures are consistent with previous reports regarding bat box effectiveness (Swift, 2004; Flaquer *et al.* 2006; Tuttle *et al.* 2013), which concluded that boxes in general should have several internal chambers and caulked or sealed joints. However, a casual examination of popular supplier websites found very few off-the-shelf boxes with these types of design measure. The expensive heated bat boxes were the only models to resemble this type of design at the time of writing. Therefore, despite the large number of bat box models currently on sale, there are likely to be opportunities for new designs to be tested. Similarly, suppliers of bat boxes should be encouraged to reveal more comprehensive details regarding internal dimensions, materials and internal compartments. Such information was consistently not available during this project. The lack of such details not only prevents purchasers from making informed choices by comparing models, but also precludes their ability to closely mimic roosts that were removed.

However, although bat box designs certainly appear to influence occupancy rates, the manner in which they are employed may be just as important. The aforementioned American-style box also happened to meet the most influential factors as proposed by Beck and Schelbert (1999, cited in Moller *et al.* 2016); namely that boxes be installed immediately after roost removal, as close as possible to the original site and with similar entrance design. The lower bat counts recorded in other bat boxes in this project may therefore be because boxes were provided outside the original building footprint, or within the footprint but long after roost removal.

Results demonstrated that both species of *Pipistrellus* spp use Schwegler 1FF and 2F bat boxes, but to varying extents. *P. pipistrellus* displayed a preference for wall-mounted 1FF boxes, whilst *P. pygmaeus* typically used tree-mounted 1FF and other woodcrete models that were both larger and cylindrical. Therefore, although our analysis indicated that each species appeared to be displaying different preferences in terms of box location and model choice, the small sample size and non-experimental nature of this project prevented us from isolating cause-and-effect relationships. Indeed, such differences may be due to species composition in the landscape or habitat preferences, particularly since the most effective bat box was for *P. pygmaeus* was also a flat-fronted and wall-mounted design, which contradicts this pattern.

Consistent with that reported by Mackintosh (2016), the heated bat boxes in our study were both largely ineffective but we were also unable to confirm whether the heating elements were functioning. Furthermore, since daytime bat box inspections during project fieldwork were typically completed in warm and sunny conditions, it is likely that thermostats would not have been triggered anyway.

Despite bat box aspect and height both being typically considered important factors when erecting boxes (McAney and Hanniffy, 2015), our own project findings did not indicate any significant relationships between these factors and occupancy rates and this was consistent with previous studies (Lintott and Matthews, 2018; Mackintosh, 2016; Bilston, 2014; Dodd and Bilston, 2013; Poulton, 2006; Rueegger, 2016).

In terms of nesting birds, Aughney (2008) and Dodds and Bilston (2013) both reported significant competition between bats and nesting birds for 1FS and 2FN boxes. Likewise, surveyors frequently recorded bird nesting and roosting signs in bat boxes during this study. Bat boxes used by birds are unlikely to be used by bats during the nesting season (Meddings *et al.* 2011; McAney and Hanniffy, 2015). Bird occupation may also require that site managers regularly appoint licensed ecologists to routinely clear out old nesting material from boxes that may also deter bats at additional cost to the project or site (Moller *et al.* 2016). Bat box monitoring schemes have attempted to reduce nesting bird competition by installing additional bird nest boxes adjacent to bat boxes, although with only limited success (Meddings *et al.* 2011; Dodds and Bilston, 2013). Aughney (2008) also suggested reducing the size of box access points and this was later proved more effective by Bilston (2014) after 1FS and 2FN entrances were reduced using expanding foam. It was considered notable that no bird signs were present in boxes with access point apertures 17mm or under. Similarly, box models with the highest instances of bird presence rates featured access points at least 25mm wide. It is therefore suggested that bat boxes with smaller openings are selected if the intention is to prevent competition with birds.

Ultimately, despite demonstrating themselves to be effective in principle, it is not clear which design or location attributes are most influential and they may be site-specific.

### 4.4.4. Access points

Access points may be particularly important components of new compensation roosts because if bats do not use them, the new host roost provision will remain ineffective even if the internal conditions are suitable. In such cases it is possible that bats simply cannot find the new access points. Alternatively, it may be that bats detect the access point but do not approach them because they fail to recognise or associate them with a viable roost resource.

As discussed in the results for this section, there may be certain design measures that can be incorporated into new access points, including those for bat boxes. For example, our data indicated that attributes such as aperture width, height and the proximity of apertures to overhangs and corners were associated with higher use-rates. It is possible that such attributes may be more important for certain species or roost types. For example, apertures in close proximity to corners or overhangs may offer predatory avoidance benefits to bats emerging from external access points earlier in the evening, such as *Pipistrellus* sp. It is also possible that certain attributes may increase effectiveness if they cause access points to more closely mimick those of naturally occurring ones that local bat colonies are already familiar with.

Despite our dataset containing information from numerous roost structures, access points were frequently not identified during baseline surveys. This was particularly notable for roosts of *P.auritus* and *Myotis* species. This may be because their access points are more difficult to detect using traditional survey techniques since these species tend to emerge during lower-light conditions and frequently from access points inside outbuildings or other structures. Furthermore, a lower proportion of new access points were confirmed to be 'in-use' during the monitoring stages compared to those that were retained. It is therefore feasible that our understanding of naturally occurring access points in buildings is limiting the design of new ones.

If bats are either unable to find new access points or are simply not looking for them, access point design may be less important than increasing access point detection rates. It has been shown that bats exchange information about roosts among colony members and use echolocation and social calls to find roosts (Schoner et al. 2010, Ripperger et al. 2019). Ruczynski et al (2007) demonstrated that using synthesized bat calls was effective at attracting *N. noctula* bats to new roosts under controlled conditions. This was later demonstrated in field conditions where *M. bechsteinii*, *M. nattereri*, and *P. auritus* all approached bat boxes significantly more frequently during nights when bat social calls were played back inside them compared to nights without playback (Schoner et al. 2010). In contrast, the use of olfactory and other non-social cues did not increase colonisation times (Schoner et al. 2007). Since acoustic social cues are likely to be of critical importance for learning about the location of new roosts and access points (Ruczynski et al 2007, Voigt et al 2016), further research investigating the application of such measures may allow future schemes to assist bats with detecting new access points.

### 4.4.5. Lighting

**Artificial lighting** can impact bats' reproductive ecology and growth rates by delaying their emergence, shortening foraging times or even causing roost abandonment (ILP, 2018; Stone *et al*, 2015b). Therefore, surveyors collected presence-absence (P/A) data on artificial light following dusk emergence surveys or before dawn re-entry surveys. Categories were broadly assessed by eye for each access point and building associated with roosting provisions. The following P/A data was recorded:

- Whether artificial lighting was directly illuminating access points.
- Whether artificial lighting was directly illuminating areas within 5m of access points.
- Whether artificial lighting was directly illuminating parts of the building other than the access points.
- Whether the presence of artificial lighting was considered likely to partially fragment the roost structure from surrounding areas of dark habitat.
- Whether the presence of artificial lighting was considered likely to totally fragment the roost structure from surrounding areas of dark habitat.

Since this assessment was intended to target instances of artificial lighting that was obstructive or disturbing to bats, only lighting considered likely to negatively influence bat behaviour was recorded rather than all artificial light present at a site. For example, certain sites adhered to mitigation strategies by installing very low-level solar lighting on footpath edges, or off-site lighting was located far enough away that any glare was generally minimal. Several sites had also installed motion-sensitive security lighting as a bat mitigation measure for minimising the length of time lighting was active. However, unless surveyors observed that such lighting was active for unusually long periods or constantly triggered by general site activity, such lighting was also excluded from this assessment, although its presence was still recorded.

Artificial lighting was reported as a likely impact in only 10% of licence method statements (n = 71). (n = 71). However, BCT recorded artificial lighting at 32% of sites where light-levels were considered likely to reduce the effectiveness of mitigation measures. This was because permanent lighting fixtures illuminated access points, areas directly adjacent to bat roosts / provisions, or general light-levels were considered to at least partially fragment roosting areas from surrounding areas of dark habitat. Such impacts were not necessarily attributed to the development itself, with 39% of these instances being caused by off-site or pre-existing light sources. However, 61% (n = 23) of these lighting impacts were within developmental control, being caused by newly-installed lighting. These were chiefly commercial sites (86%, n = 14) and particularly care homes. Method statements for 87% of these cases (n = 23) did not reference artificial lighting as a potential impact.

Planning conditions for 16% of sites (n = 71) specified that LPAs formally agree site-wide lighting strategies in advance of construction. Such details were generally not available to BCT for close examination so we could not accurately assess compliance or levels or ecological input (if any). Indeed, only one method statement (1%) proposed that ecological input would be fed-into a sensitive lighting strategy by a professional lighting designer. Artificial lighting schemes at 33% of these sites (n=12) were both at-odds with licence method statements and considered reasonably likely to negatively impact bat roost occupancy rates. Again, all such instances were commercial developments rather than domestic residences.

In terms of the light mitigation strategies themselves, most method statements simply proposed the avoidance of artificial lighting altogether (38% of sites, n = 71). In terms of the individual light-avoidance strategies, 25% of sites proposed that new light sources be directed away from roosts and access points. Although 79% (n = 18) of these were fully compliant, two sites (11%) were non-compliant because access points were permanently lit. Two others (11%) were considered partially-compliant because they were periodically lit by a motion-sensitive source on a short timer (11%). Likewise, several sites (23%, n=71) specified the use of motion-sensitive security lighting as a mitigation measure. This was not fulfilled in two cases because lighting was permanently switched-on. However, five of these sites did not feature any external lighting at all - motion-sensitive or otherwise. In contrast, several sites continued to have significant lighting levels despite technically complying with all proposed mitigation requirements, for example: "no lighting will be installed near the maternity roost', or 'no lighting will shine directly on bat roost entrances'.

Although it was beyond the scope of this study to comprehensively assess how artificial lighting may have affected roosting bats in our sample, artificial lighting at 32% of sites was nonetheless considered reasonably likely to have reduced the effectiveness of installed provisions. Ultimately, the true effect of implementation may have wider implications that cannot be detected at the site-level.

It is therefore essential that ecologists are given the opportunity to feed-into lighting strategies whenever licence development is considered likely to impact bats (ILP, 2018 – this guidance was published after completion of development and monitoring at the sites involved in this study). It is important that developers, planning officers and ecologists themselves take reasonable steps to ensure they are included in such decisions (Mackintosh 2016).

Although critically assessing lighting strategies is a key skill for bat workers, lighting plans can be highly complex and technical, so ecologists may struggle to 'visualise' how lighting strategies will appear when complete. It is therefore essential that ecologists can take professional advice and guidance from lighting specialists. Night-time compliance checks by ecologists and lighting engineers may also help, particularly if there is a planning requirement for ecologists to sign-off certain aspects of a lighting strategy after implementation. However, this would only be effective if there is scope for retrospective modifications if issues are identified and compliance checks are followed through by the LPA and / or SNCBs.

### 4.4.6. Surrounding habitat and wider landscape

Habitat is acknowledged to be an important factor in bat roost selection (Entwistle *et al.* 1997; Boughey *et al.* 2011; Lintott *et al* 2016). However, no specific measurements were quantified for detailed assessment, simply because accounting for the variability, complexity and scale of surrounding habitat in terms of bat mobility and core-sustenance zones (BCT, 2016), as well as the degree to which it may have been associated with on-site roost function, was both beyond the scope of this project and not considered feasible with the available resources. However, surrounding habitat land-use and the presence of key attributes such as watercourses, woodland and hedgerows were nonetheless described and photographed *in-situ*. Furthermore, the quality of commuting habitat between the on-site roosting provisions and surrounding countryside was categorised as 'excellent', 'moderate' or 'poor' in line with page 35 of BCT's Good Practice Guidelines (Collins, 2016).

In terms of habitat proposals, 18% proposed habitat enhancement or creation measures. Permanent or temporary habitat losses during development were only anticipated at eight sites (11%, n=71), all of which were commercial developments. This was because developments were generally small-scale or restricted to pre-existing built footprints. Although it was not always possible to accurately determine the extent of any habitat-related impacts using the baseline information, the quality of nearby commuting habitat was assessed according to page 35 of BCT's Good Practice Guidelines (Collins, 2016). Most sites (70%) were categorised as having 'excellent' commuting habitat, 28% as moderate and only a single site (2%) considered to be 'poor' in terms of quality. Almost all sites were situated in rural or semi-rural parts of lowland England and Wales.

Although method statements for 45% of sites proposed that habitat features would be retained, it was not always possible to accurately determine the extent of any habitat-related impacts using the baseline information because detailed habitat information was not typically available. Without access to paper-trails documenting the decision-making process, it was not possible to determine whether such retention measures were embedded into developmental designs or that habitats were never intended to be removed anyway. Therefore, there was no evidence to indicate whether habitat impacts had taken place or not.

Several sites (10% n = 71) proposed habitat enhancement measures to existing features, such as strengthening existing flight-lines or re-planting vegetation around roost entrances. Such enhancements were absent at 43% (n = 7) of these cases. Similarly, seven sites (10%) proposed habitat creation measures that were also partially absent at three sites (43%, n = 7).

Planning conditions for 33% (n = 71) of case studies specified the protection, reinstatement or creation of habitat features. These included protection measures for trees and other boundary features during construction. They also included requirements for LPAs to approve landscape plans in advance of construction and that schemes adhere to approved landscape plans.

Although most schemes (92%, n = 34) were considered broadly compliant by BCT surveyors, 8% were considered only partially compliant because certain habitat features were recorded as absent during the operation phase.

Drayson and Thompson (2015) reported that whilst overall implementation rates for habitat mitigation schemes in their sample were relatively high, effectiveness was highly variable and concluded the two outcomes were not necessarily directly related.

Bat presence and abundance changes may also be more causally related to factors in the wider landscape such as roost availability rather than impacts on-site (Feyerabend and Simon, 2000; Bartonička *et al.* 2008, Lintott and Matthews, 2018). For example, despite the importance of roost sites, it is still unclear whether roosts are limiting factors for bat populations (Mering and Chambers, 2014) and this may be more important for certain species like *P. auritus* (Entwistle *et al.* 1997). For example, two of the most effective new provisions in this project were cited in very rural areas with low building densities so there may have been a scarcity of similar alternative structures.

Clearly more research into both the long-term and short-term population effects of roost removal is required (Stone *et al.* 2015a). This would allow SNCBs to make more informed decisions regarding the FCS of bat species and ecological consultants more confidence in certain mitigation approaches (Mackintosh, 2016). However, in addition to more focused and small-scale research, collecting larger-scale data on mitigation effectiveness over wide areas and extended time periods could be a powerful tool for UK bat conservation. Such data could be obtained directly from existing post-development monitoring programs and this is discussed further in Section 7.

## 4.5. Recommendations

- Continued engagement with roost owners (e.g. through BCT's Helpline) should be supported to address misunderstandings about bats and prevent future conflict in development situations.
- Awareness should be raised among all stakeholders that schemes involving roost loss and then compensation in new buildings (such as bat houses or lofts) are less likely to be effective than modifying or retaining bat roosts.
- When assessing the impact of a scheme, SNCBs should continue to acknowledge the reduced efficacy of roost compensation schemes in comparison to schemes involving roost retention or adaptation of existing buildings. The mitigation hierarchy should be consistently applied and licences refused where appropriate.
- Further investigation should be prioritised to better understand the roosting ecology of brown long-eared and *Myotis* bats. In particular: how they find new roosts, the importance of the availability of different microclimates, optimal conditions for light sampling behaviours and the influence of texture/smell of new materials on occupancy and the possible role for using old materials, ideally from the lost roost. New technologies such as thermal imaging may provide an opportunity to further our understanding.
- Further investigation is recommended to explore the possibility of attracting bats into new roosts through acoustic or other cues.

- Compensatory roosts (excluding hibernation roosts not covered in this research) should prioritise occupied buildings over unoccupied buildings where appropriate for the species covered in this project until further research finds the limiting factor for unoccupied buildings.
- Further research is recommended to assess the relationship between bat numbers and orientation of bat boxes.
- Further research is recommended to investigate the impact of grip lines beneath bat access points.
- Existing and new bat box designs should be subject to field testing for different species.
- In this study common pipistrelle displayed a preference for wall-mounted Schwegler 1FF boxes but soprano pipistrelle typically also used tree-mounted 1FF or other woodcrete models as well. Species-specific preferences like these, and others in this report, should be carefully factored into decisions-making when planning/designing bat mitigation strategies.
- Bat box suppliers should be encouraged to publish full specifications for their boxes (including in particular, internal dimensions, materials, compartments and whether joints are sealed) to allow customers to make informed choices and most closely match compensatory roosts with the original.
- Where possible, bat boxes should be erected before roost removal, as close to the original roost as possible and with a similar entrance design.
- New bat box designs (or bat boxes selected for compensatory roosts) should feature smaller openings for bat access (preferably less than 25mm and ideally less than 17mm) to prevent competition with birds.
- The use of heated bat boxes should be discouraged unless absolutely necessary, due to the potential unreliability of the heating system or operators and the difficulty of monitoring operation.
- Further research is recommended to investigate the relationship between bat counts and the number of retained/modified access points as compared to new access points.
- Further research is recommended to investigate the use-rate for retained/modified access points.
- Bat use is influenced by the aperture width of new bat access points in structures; these should ideally be between 13 and 22mm.
- Bat use is associated with some form of corner or overhang at 90 degrees to the opening; ideally new access points should include such features, particularly where such features were identified during baseline surveys.
- Detail of existing lighting and the potential impacts of lighting post-construction should be considered in all licence applications.
- Where lighting strategies are being designed by specialists for proposed developments, ecological consultants should take the opportunity to feed in information about bats at the start of this process. Awareness should be raised among developers and lighting engineers of the importance of this and it is particularly important for commercial sites such as care homes.
- Detail about existing habitats surrounding sites, potential impacts on habitats and mitigation/compensation measures should be provided in all licence applications.
- Further research should be conducted to establish the impacts of roost removal on populations of relevant species in both the short and longer-term.
- Metadata relating to licensed development work should be systematically collected/collated into a database as part of the licensing process to allow for future analysis of the level of implementation of different provisions.
- Any improvements in the practice of ecological consultants could be facilitated in the longer-term through the Earned Recognition Project, a partnership project involving NE, BCT and the Chartered Institute for Ecology and Environmental Management (CIEEM). Sufficient resources should be dedicated to the continuation of this project.

# 5.0. Species specific effectiveness

## 5.1. Background

Previous studies have reported species-specific differences in terms of post-development occupancy rates. For example, Waring (2011) reported that *R. hipposideros* mitigation schemes were noticeably more successful than *Pipistrellus* spp. Likewise, Lintott and Mathews (2018) reported *P. auritus* schemes were noticeably more effective at maintaining their pre-development abundance counts compared to *Pipistrellus spp*. It was put forward that higher occupancy rates for *P. auritus* may have reflected a stronger level of roost loyalty or a scarcity of suitable alternative roosts (Entwistle *et al.* 2000; Lintott and Mathews, 2018).

The nature of a development's impact has also been demonstrated to influence the effectiveness of mitigation schemes. For example, Briggs (2004) recorded evidence of bats in only 22% of developed units compared to 100% of un-developed ones. Likewise, Mackintosh (2016) reported that schemes involving modification were generally the most effective at retaining bat abundance. Lintott and Mathews (2018) also concluded that mitigation success was strongly related to the nature of the impact, and that mitigation schemes were more likely to be effective if the original roosting space and access points were retained or modified compared to removed.

## 5.2. Methods

It was not possible to examine differences between impact types and species using the site-level assessment criteria described. This was because most sites in BCT's sample featured more than one target bat species and more than one type of impact (e.g. roost removal, or damage / modification). The dataset was therefore refined by dividing the 71 case studies into 180 separate mitigation 'schemes' according to the species.

In the interest of isolating relationships with particular species, cases where baseline roosts were used by 'unknown' species were excluded. Also excluded were schemes for *Pipistrellus* spp when both *P.pipistrellus* and *P.pygmaeus* were affected at the same site. Schemes were also categorised on the basis of roost status to examine any differences between sites with and without maternity colonies. However, several sites featured both higher-status maternity roosts and lower status day-roosts of the same species. In these instances, schemes were simply categorised according to the highest-status roost on site (Table 4.4).

For each scheme, the conservation outcomes listed in Table 4.3 were adapted for being species-specific and are listed in Table 5.1. Post-development monitoring results were then used to assess schemes using these adapted outcomes. Post-development monitoring data from both the consultant and BCT monitoring stages were combined for this assessment.

**Table 5.1.**

*Criteria for assessing species-specific schemes at post-development sites*

| **Conservation outcomes for species-specific schemes** | |
|---|---|
| Outcome | Description |
| 1b | Site retained the presence of the target bat species |
| 2b | Site maintained or increased target bat species abundance levels |

## 5.3. Results

Figure 5.1 displays the species composition of lower or higher status roosts recorded during BCT's monitoring surveys. *Pipistrellus* spp roosts were recorded most frequently (60% of active roosts) followed by *P. auritus* (21%). Note that this breakdown includes 11 structures used by more than one species (i.e. roosts of multiple occupation). We also recorded 15 new bat roosts in retained or un-modified parts of buildings that may have been colonised since the baseline stage. Since these roosts were not technically in new, modified or retained provisions, they were therefore excluded from analysis when these provisions were being compared. Nevertheless, these 15 records were used to inform our assessment of post-development bat presence on sites.

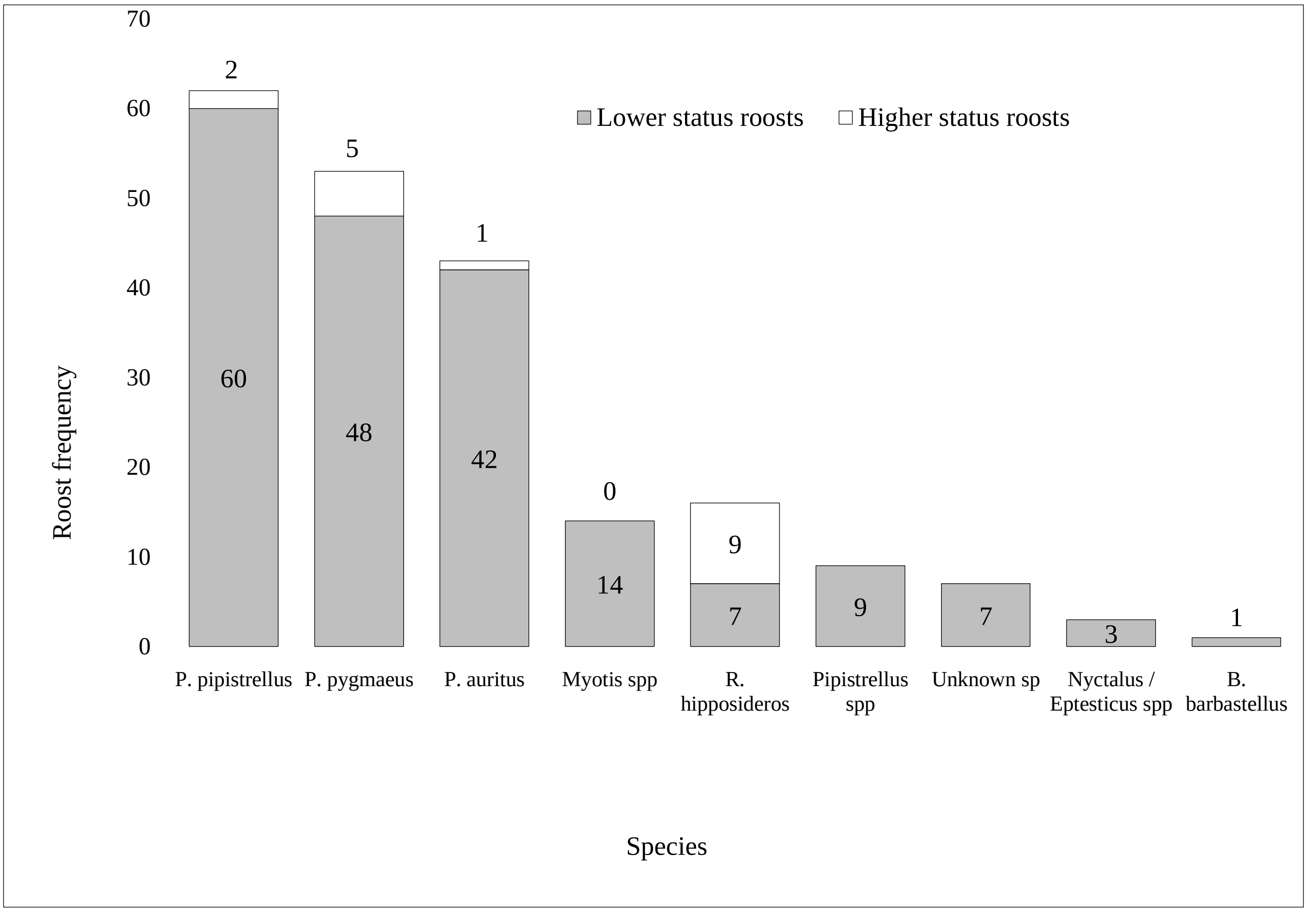



**Figure 5.1**

*Species recorded during BCT's post-development monitoring*

During the baseline stage, roosts of *Myotis* spp were recorded in approximately equal proportions to those of *P. pygmaeus*. However, it was apparent early on that we were recording a noticeably lower frequency of *Myotis* spp roosts during our own monitoring. To compensate for this low sample size, the following *Myotis* spp roosts were combined at the genus level during data analysis. Whilst it is acknowledged that these species have very different requirements this approach was taken because there is low confidence that species were identified correctly during baseline surveys, particularly as this was before the more widespread use of DNA analysis.

- *M. mystacinus* – four roosts
- Daubenton's bat *Myoti*s daubentonii – one roost

- Bechstein's bat *Myot*is bechsteinii – two roosts
- *M. nattereri* – one roost
- Unknown *Myotis* spp – six roosts

Despite being the UK's most widespread species of this genus, *M. nattereri* was only confirmed on a single occasion via direct observation inside a loft void.

Figure 5.2 displays the frequency of sites proposing to impact particular species and roost status. Figures 5.3 and 5.4 summarise the degree to which post-development monitoring surveys recorded that such schemes had retained species presence or maintained / increased abundance levels.

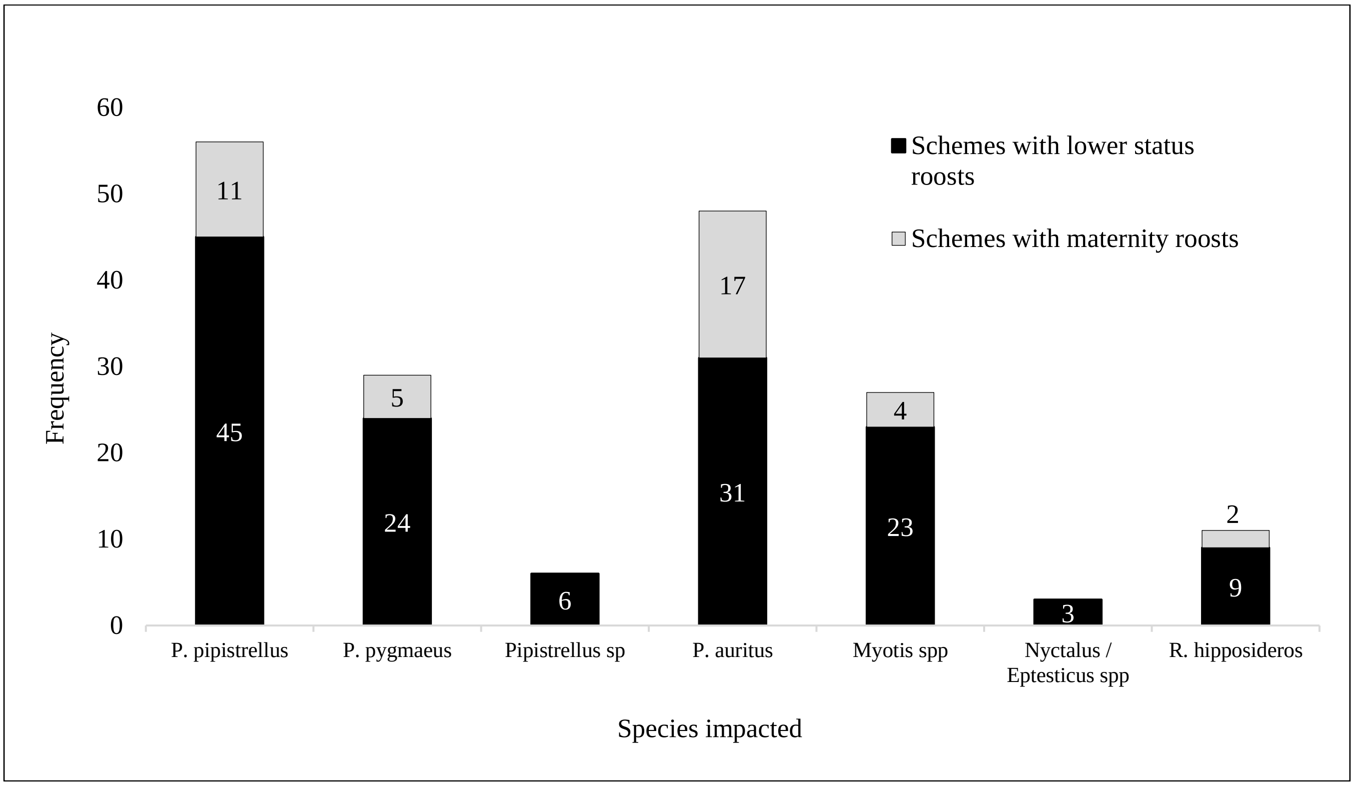



**Figure 5.2**

*Frequency of species-specific mitigation schemes in BCT's sample*

When only accounting for bat presence (as opposed to abundance levels), 69% (n = 39) of schemes impacting higher status maternity roosts retained the target bat species. This was therefore a higher level of retention compared to schemes affecting roosts of lower-status where 52% (n = 141) retained the target species. This was the case for all species and most pronounced for *P.pipistrellus* in which 58% of lower status schemes retained species presence compared to 82% of maternity schemes. It was least pronounced for *P. auritus* where both lower and higher status schemes were approximately equal (55% and 59% respectively). Retaining species presence was recorded least frequently for schemes involving *Myotis spp* (33%, n = 27).

In contrast to simply retaining species presence, maintaining or increasing abundance levels was recorded less frequently for all species, including *P.pipistrellus* (32%, n = 56), *P. auritus* (27%, n = 48) and *Myotis* spp (19%, n = 27). However, abundance levels were maintained noticeably more frequently for *R. hipposideros* (45%, n = 11) and *P. pygmaeus* (41%, n = 29) schemes.

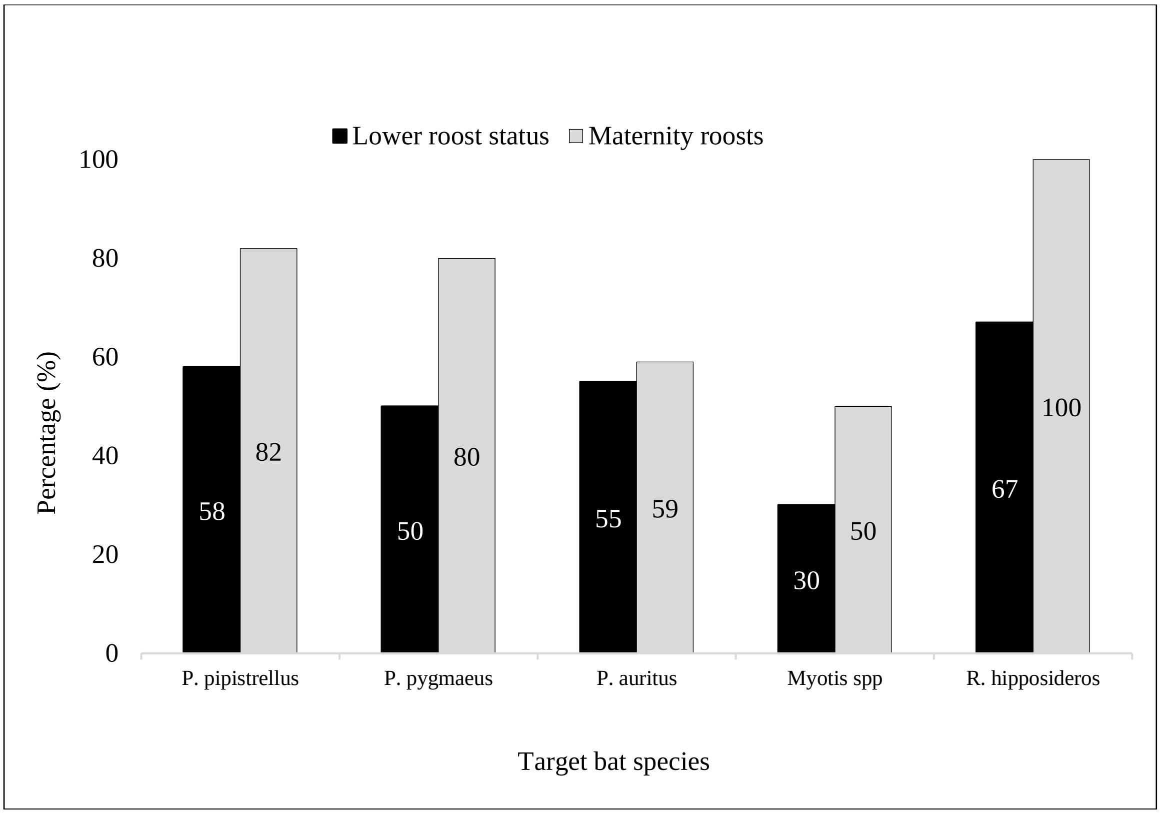



**Figure 5.3**

*Proportion of schemes retaining species presence*

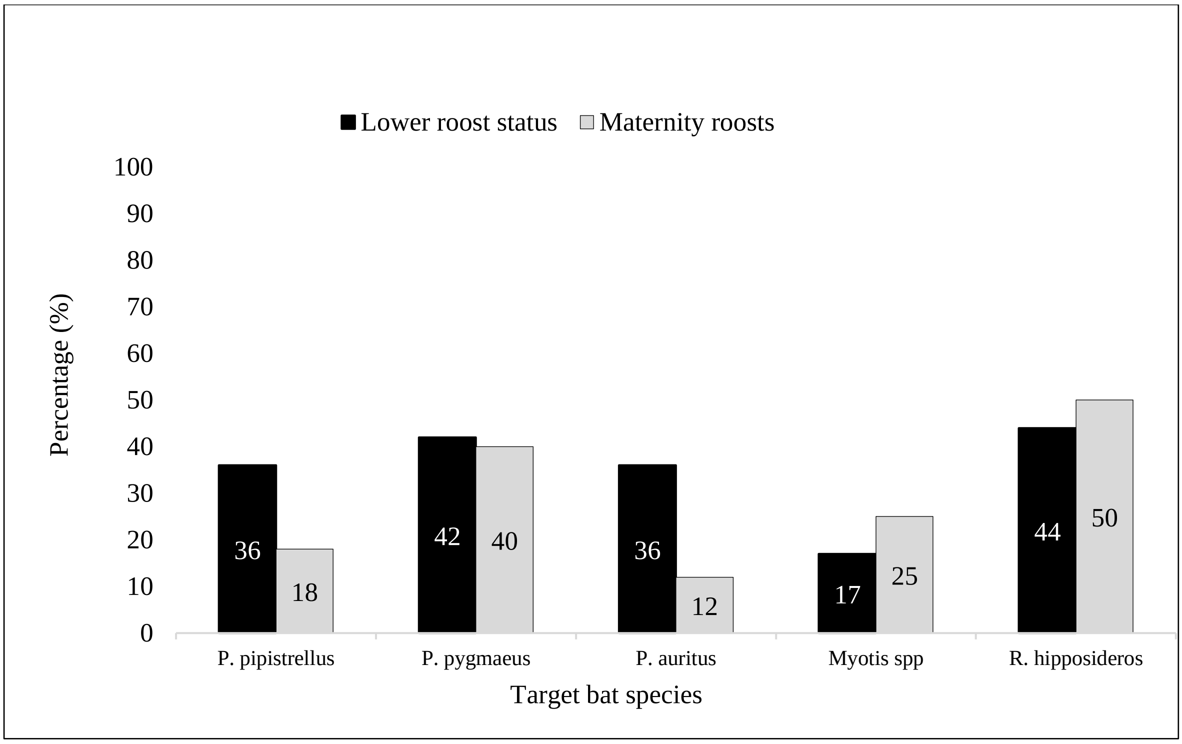



**Figure 5.4**

*Proportion of schemes maintaining or increasing species abundance*

In contrast to retaining species presence, a lower proportion of schemes with higher-status roosts maintained abundance levels (21%, n = 39) compared to those with lower status roosts (34%, n = 141). This was most pronounced for *P.pipistrellus* and *P. auritus* where noticeably lower proportions of maternity schemes maintained abundance counts compared to schemes with lower-status roosts. However, this was not the case for *R. hipposideros* where a slightly higher proportion of maternity schemes maintained numbers. The proportions were also relatively equal for *P. pygmaeus* schemes.

Species preferences for new provisions were compared to baseline and non-intended roosts for differences and similarities between the two classes. As with new provisions, chi-squared tests for baseline and non-intended roosts indicated highly significant differences in species presence-rates between sub-groups (chi-squared = 243.49 with 30 d.f., $p < 0.001$***).

Notwithstanding the relatively high frequencies of *P. auritus* in roof and outbuilding voids, they were also frequently recorded using internal cavity roosts. Although most baseline and non-intended internal cavities were ‘unknown’, when the 30 verified internal structures were assessed in isolation, 53% (n = 30) were used by *P. auritus* compared to *P.pipistrellus* (27%), *P.pygmaeus* (0%) and *Myotis* spp (6%). The proportion of ‘unknown’ roost structures was noticeably higher for *Myotis* spp, representing 43% (n = 54) of all baseline and non-intended *Myotis* spp roosts compared to 27% (n = 96) of *P. auritus* and 28% (n = 299) of *Pipistrellus* spp roosts.

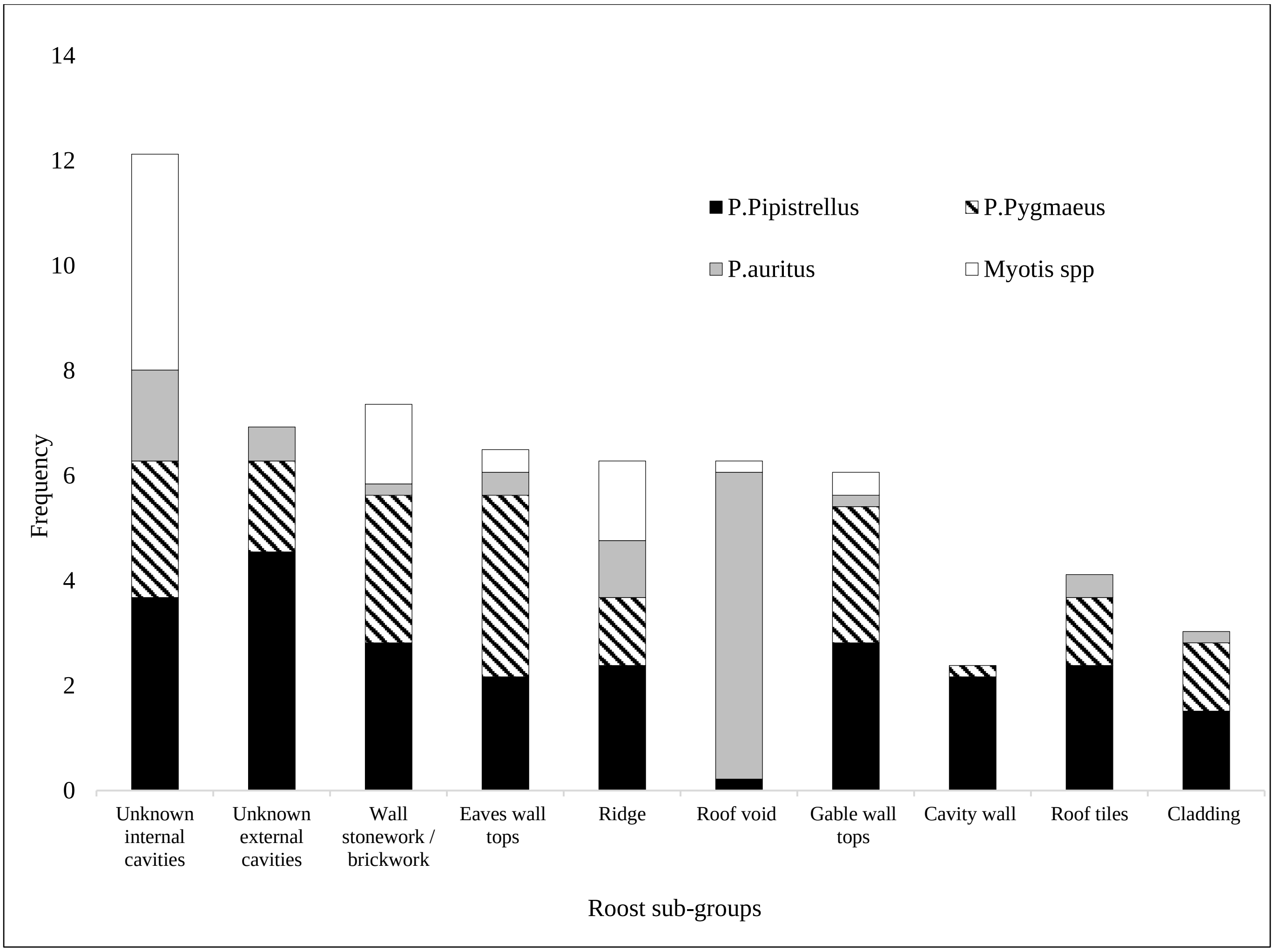



**Figure 5.5**

*Species composition of roost sub-groups*

Figure 5.5 shows the species composition for new provision sub-groups. Chi-squared tests for bat presence rates indicated highly significant differences in sub-group selection between species (chi-squared = 58.48 with 15 d.f., $p < 0.001$***).

*Myotis* spp were recorded least frequently, accounting for only 8% (n = 128) of occupied provisions. This prevented meaningful quantitative analysis of this genus' roost selection preferences.

Although *P. auritus* was recorded less frequently than *Pipistrellus* spp, they occupied a noticeably higher proportion of occupied bat lofts when compared (73% and 18% respectively, n = 11). Likewise, although small internal cavity roosts had significantly lower occupancy rates than the other main groups, *P. auritus* were present in 64% (n = 11) of these provisions when they were occupied. Such provisions included internal bat boxes, internal boarding / panels and the tops of internally dividing walls.

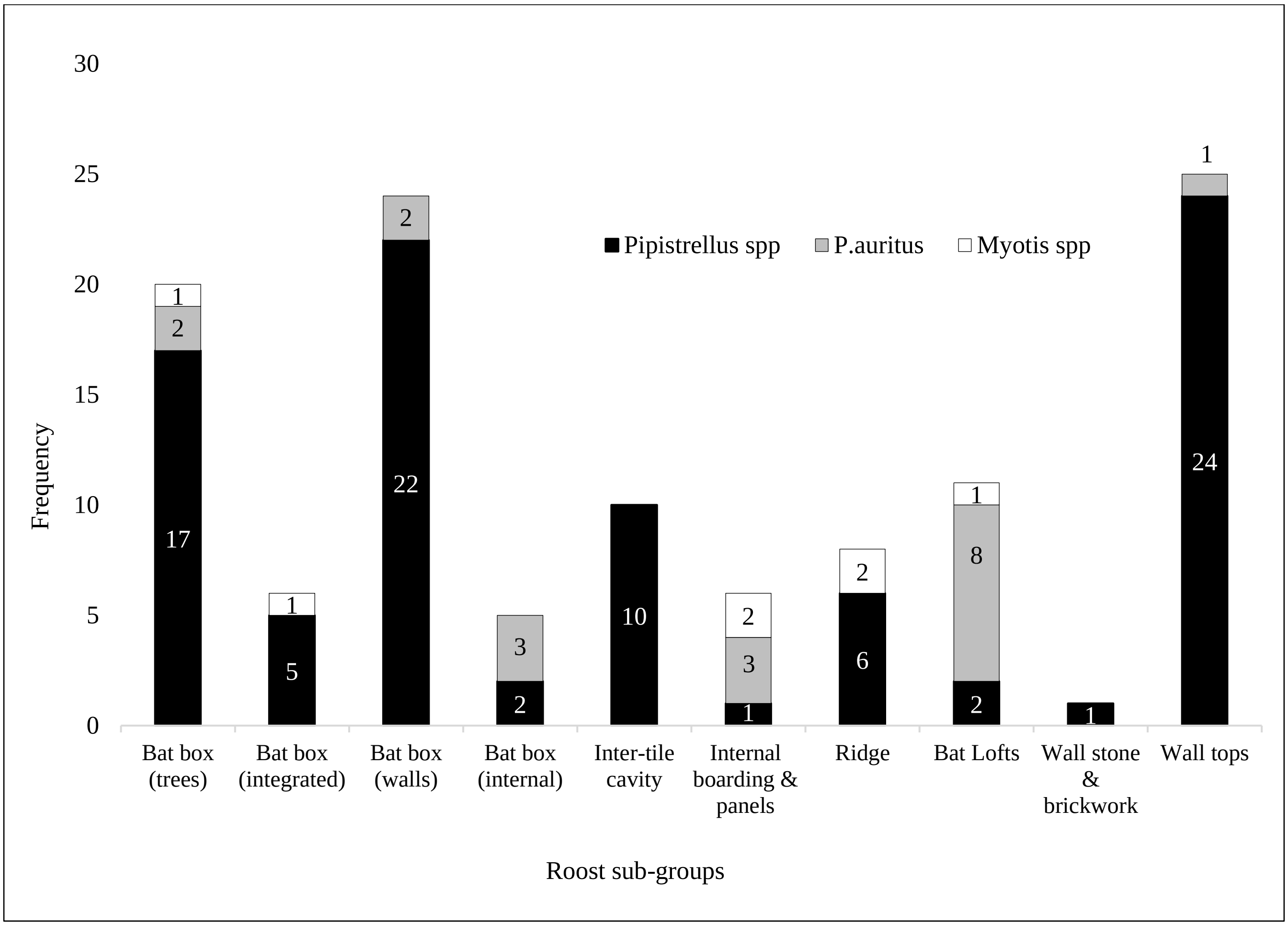



**Figure 5.6**

*Species composition of new provision sub-groups*

*Pipistrellus* spp demonstrated a clear preference for small external cavities and were recorded in 89% (n = 102) of these roost types when they were occupied (Figure 5.6). Likewise, 94% (n = 97) of all *Pipistrellus* spp roosts in newly-installed provisions were small external cavities as opposed to internal cavities (4%) or voids (2%).

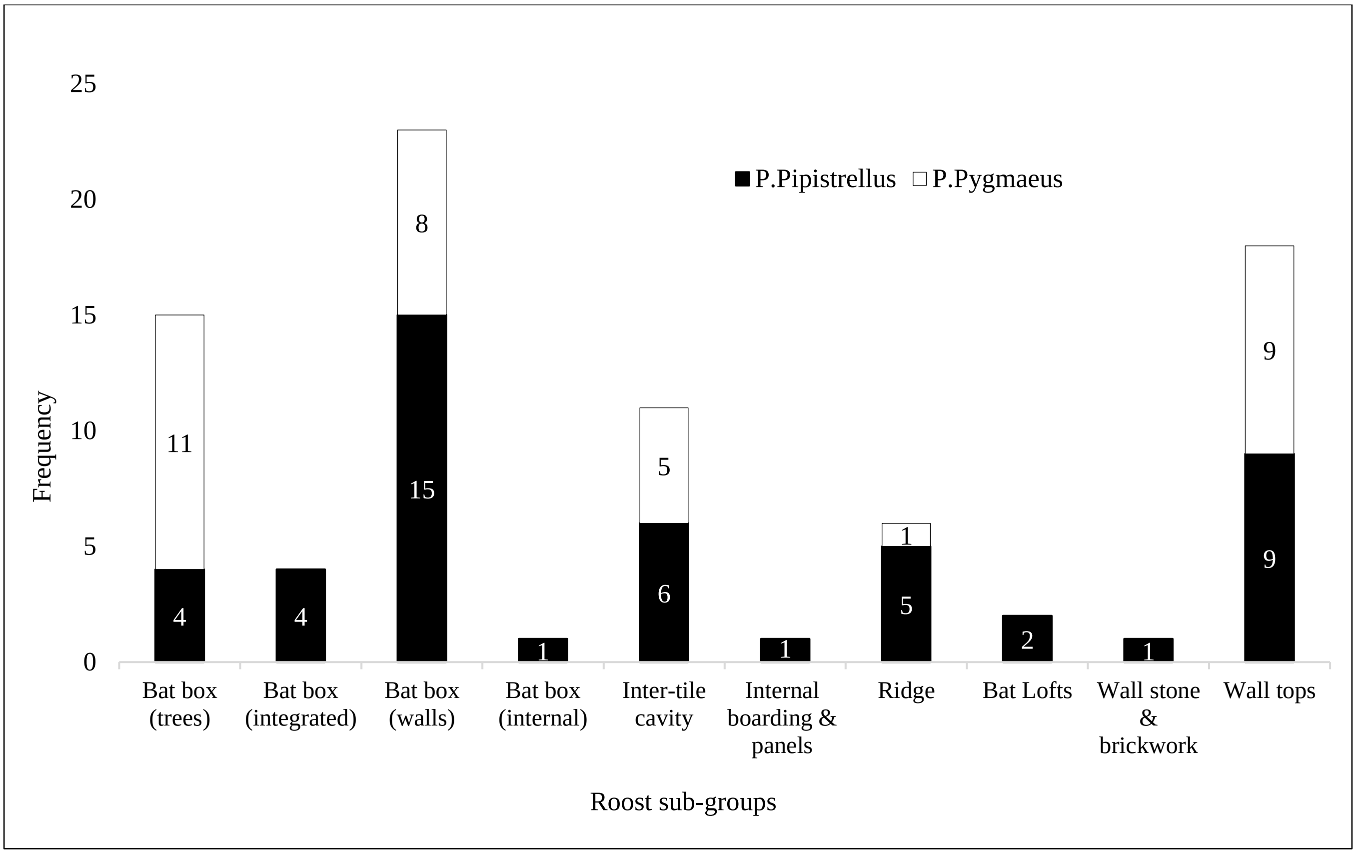



**Figure 5.7**

*Pipistrellus spp composition of new provision sub-groups*

When assessed separately Figure 5.7 demonstrated that *P.pipistrellus* displayed a noticeable preference for wall-mounted and wall-integrated bat boxes, while *P.pygmaeus* displayed a preference for tree-mounted boxes. However, both species were recorded using wall tops and inter-tile / lining cavities in approximately equal proportions. It is therefore possible that such differences may be attributed to habitat and landscape-related factors.

## 5.3.1. Species Preferences – access points

The GLMM model indicated there were large and significant differences between bat species groups in their use of internal and external access points (chi-squared = 68.07 with 3 d.f., $p < 0.001$***). In particular, 82% (n = 120) of all access points were used by *Pipistrellus* spp and these were primarily external. In contrast, despite only 10% of access points being attributed to *P. auritus*, these were spread fairly evenly between those that were external and internal.

In terms of access point sub-groups, the GLMM model continued to indicate highly significant inter-species differences (chi-squared = 118.57 with 30 d.f., $p < 0.001$***). Again, this was predominantly due to the stark differences between *Pipistrellus* spp and *P. auritus*, this latter species using a significantly higher proportion of larger indirect openings. Differences between *P. pipistrellus* and *P. pygmaeus* were slightly less pronounced (chi-squared = 25.69 with 10 d.f., p = 0.004**), particularly for stonework gaps, wall top crevices and bat boxes. However, *P. pipistrellus* did display a preference for roof tiles in this study (including ridge, hanging, field, hip and edge tiles) compared to *P. pygmaeus*.

Although the model indicated that *Myotis* spp also displayed differences to the other species, discerning them was generally problematic due to the low sample size for this group. The most notable difference was that *Myotis* spp were responsible for a lower proportion of wall top access use compared to the other groups, with only 3% (n = 39) of such access points being used by *Myotis* spp.

When active access points within the 10-35 mm range were examined in more detail (Figures 5.8 and 5.9), the most frequently used for all species were those with apertures of 13-22mm (84%, n = 143).

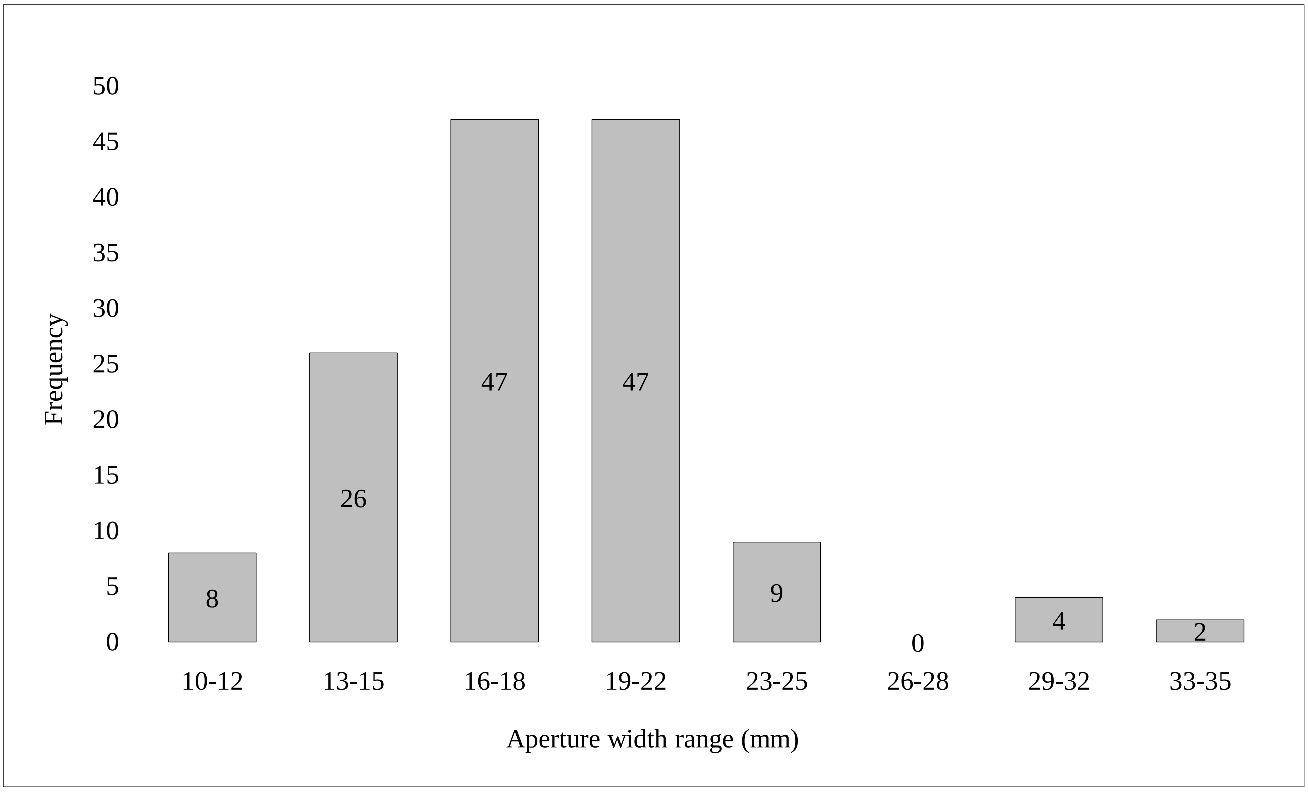



**Figure 5.8**

*Frequency of Pipistrellus spp access points with different widths*

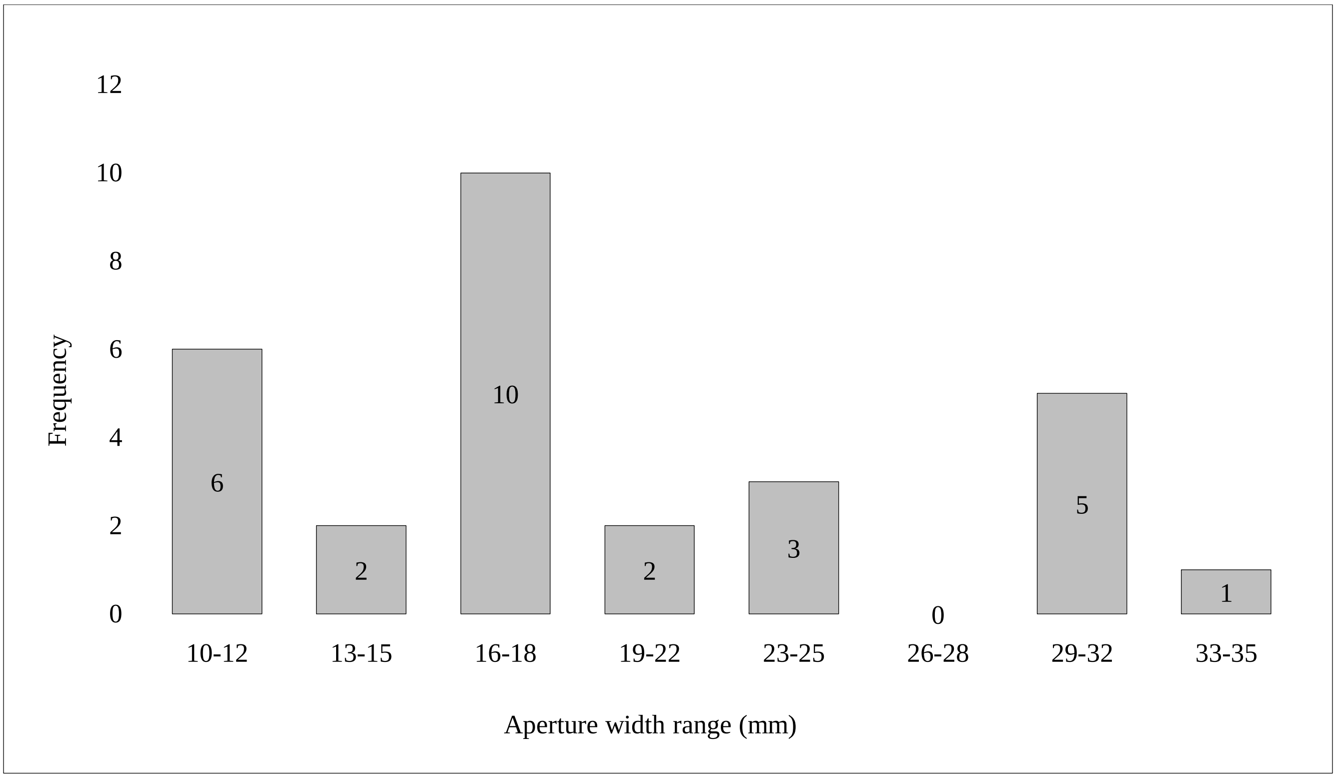


**Figure 5.9**

*Frequency of P. auritus and Myotis spp access points with different widths*

### 5.3.2. Species preference – bat boxes

Figure 5.10 shows the species composition using bat boxes with different mounting locations. *P.pipistrellus* occupied external wall-mounted boxes most frequently, this mounting location group being responsible for 65% (n = 24) of this species' presence in boxes compared to tree-mounted boxes (19%). In contrast, tree-mounted boxes were responsible for 52% (n = 18) of *P.pygmaeus* presence in boxes compared to wall-mounted boxes (35%). Despite low occupancy rates for both *P.auritus* and internally-mounted boxes, this species was responsible for 75% of 'active' internal boxes. However, no live *P. auritus* bats were ever recorded and two of these boxes were present inside voids where signs of use were more pronounced outside the boxes. These species-specific variations were not confirmed by the binomial GLMM model where presence-absence differences of these species between box-mounting locations were not statistically significant (chi-squared = 5.57 with 3 d.f., p = 0.136). However, it was not possible to determine whether this result was due to an inadequate sample size or a genuine reflection of random events.

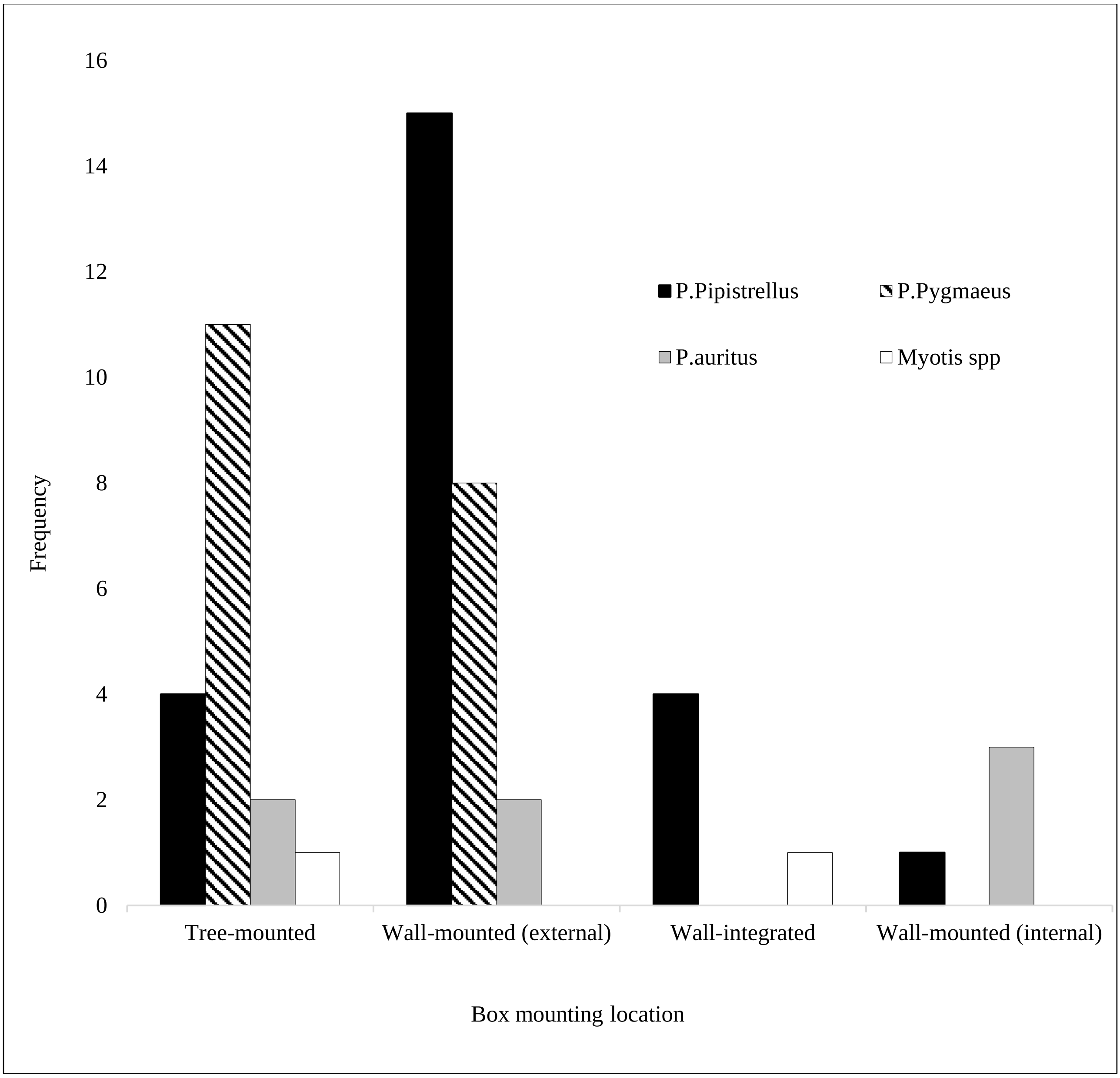


**Figure 5.10**

*Species composition in bat boxes of different mounting categories*

Results demonstrated that both species of *Pipistrellus* spp use Schwegler 1FF and 2F bat boxes, but to varying extents. *P. pipistrellus* displayed a preference for wall-mounted 1FF boxes, whilst *P. pygmaeus* typically used tree-mounted 1FF and other woodcrete models that were both larger and cylindrical. Therefore, although our analysis indicated that each species appeared to be displaying different preferences in terms of box location and model choice, the small sample size and non-experimental nature of this project prevented us from isolating cause-and-effect relationships. Indeed, such differences may be due to species composition in the landscape or habitat preferences, particularly since the most effective bat box was a flat-fronted and wall-mounted design occupied by *P. pygmaeus*.

In terms of species selection, 58% (n = 24) of boxes with *P.pipistrellus* presence were under 2,000 cm3, compared to 11% (n = 19) for *P.pygmaeus*. Similarly, only 42% of *P.pipistrellus*-occupied boxes were over 5,000 cm3 compared to 89% for *P.pygmaeus*. The GLMM model also reported this relationship to be statistically significant (chi-square = 5.26 with 1 d.f., p = 0.02*). However, this relationship may be indirectly influenced by the bat box model or mounting location, with 94% (n = 19) of active boxes under 2,000 cm3 being the 1FF design and larger occupied boxes being tree-mounted woodcrete models.

Most bat box models in our sample were mutually exclusive to their mounting location. For example, all 2F boxes were mounted on trees and all 1FQ boxes were mounted on external walls. It was therefore not possible to single-out which variable had the strongest influence on species occupancy rates in most cases. However, 1FF box frequencies were fairly equally distributed between those mounted on external walls (n = 18 at 4 sites), internal walls (n = 17 at 4 sites) and trees (n = 18 at 7 sites). Although the sample size was too small to justify statistical analysis, it was nonetheless noted that *P.pipistrellus* was responsible for 92% of the occupied 1FF boxes on external walls, compared to *P.pygmaeus* which was responsible for only 8%. Only a single tree-mounted 1FF box was occupied at a single site, and this was by *P.pygmaeus*. Furthermore, despite *P.pygmaeus* being recorded at three sites where alternative tree-mounted models had been installed alongside the 1FF design, this species was only recorded once in the 1FF model. Although this may suggest a difference in bat box preferences between *P.pipistrellus* and *P.pygmaeus*, it must be noted that both were recorded using the 2F and 1FR / 2FR designs in equal proportions.

### 5.3.3. Roost Removal Schemes

Since schemes based around roost removal were responsible for the largest proportion of schemes in our sample, this was examined in more detail and presented in Figures 5.11 and 5.12.

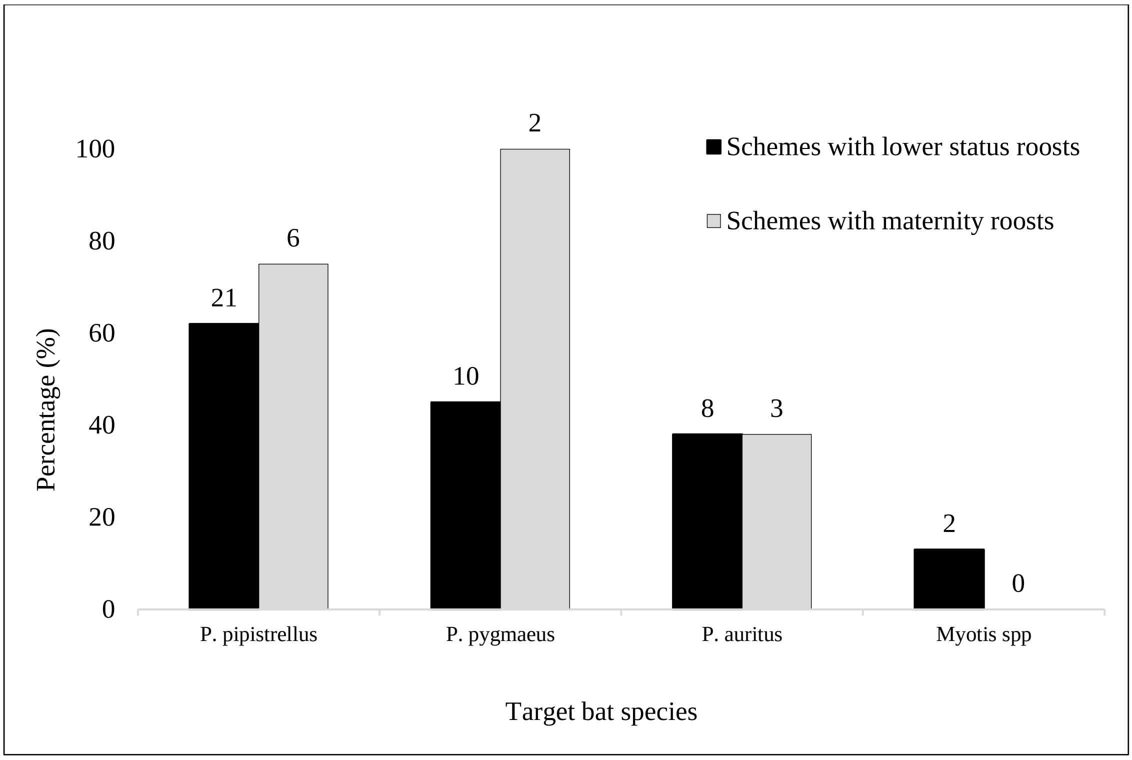



**Figure 5.11**

*Proportion of roost removal schemes retaining species presence*

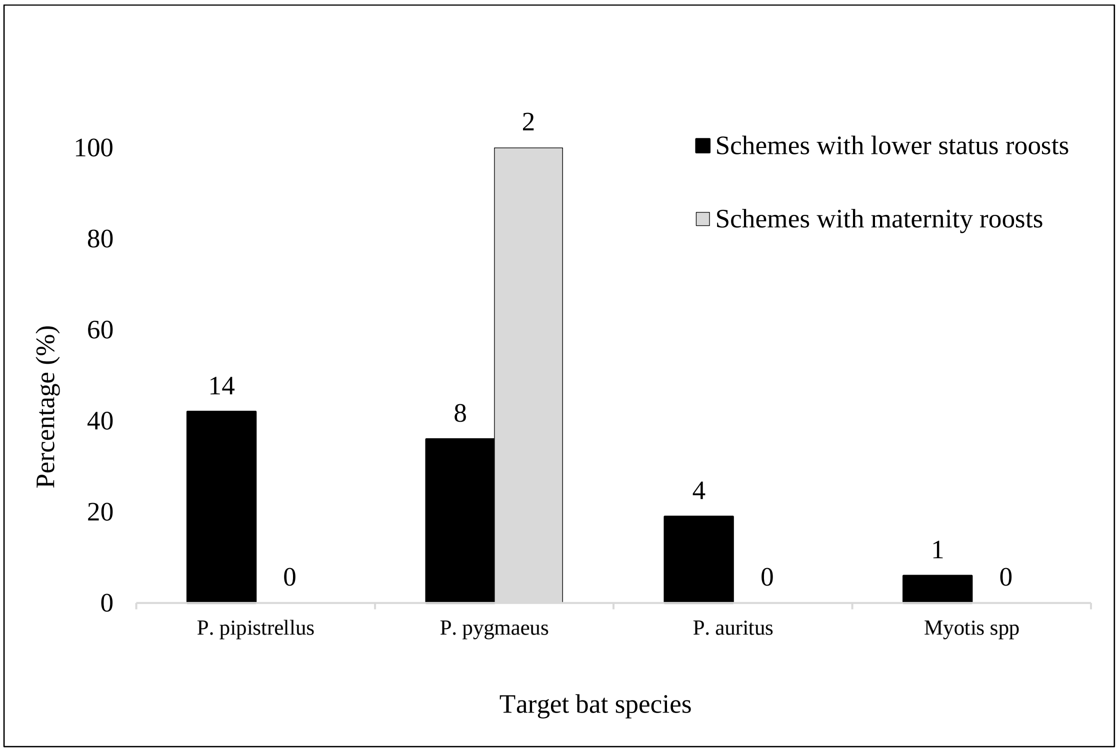



**Figure 5.12**

*Proportion of roost removal schemes maintaining or increasing species abundance*

When accounting for target species presence (as opposed to abundance), a lower proportion of schemes retained target bat species if they had removed lower-status roosts (44%, n = 93) compared to higher-status maternity roosts (58%, n = 19). This was the case for both species of *Pipistrellus* spp but not *Myotis* spp where only a single scheme involved removing a maternity roost and no bats returned post-development. Re-colonisation rates were approximately equal for lower and higher-status *P.auritus* schemes. Generally, *P.pipistrellus* were the most effective at retaining species presence (62%, n = 34) compared to other lower-status schemes.

In terms of maintaining pre-development abundance levels, lower-status schemes of *Pipistrellus* spp (39%, n = 56) were more effective than *P. auritus* (19%, n = 21) or *Myotis* spp (6%, n = 16). However, the only species to maintain abundance levels after removing maternity roosts was *P. pygmaeus* (100%, n = 2), although the very small sample size means that this result should be viewed with caution. No roost removal schemes for higher-status *P.pipistrellus*, *P. auritus* or *Myotis* spp colonies maintained their pre-development abundance levels or maternity colony status during the monitoring period.

### 5.3.4. Brown long-eared bat

Although schemes based around modification only accounted for only 9% (n = 160) of schemes, those of *P. auritus* were responsible for a larger proportion (57%, n = 14) compared to other species. Therefore, this species-impact combination was singled out for further examination.

For *P. auritus* schemes based around roost removal, 38% (n = 29) retained species presence (not necessarily maintaining abundance levels) post-development. In contrast, *P. auritus* presence was retained at 88% (n = 16) of schemes based around roost retention, modification or a combination of impact types. This was noticeably higher than the gross average rate of 56% (n = 180) for target species presence across all schemes.

In terms of maintaining abundance levels, this was achieved more frequently for schemes modifying both higher and lower-status roosts with a mean of 50% (n=8). Again, this was noticeably higher than the gross average rate of 31% (n = 180) for maintaining abundance levels across all schemes. For comparison, only 14% (n = 29) of *P. auritus* roost removal schemes maintained abundance.

Figures 5.13 and 5.14 display paired dot plots comparing maximum *P. auritus* counts between baseline and post development monitoring levels for both roost removal schemes and modification / retention / combined schemes respectfully.

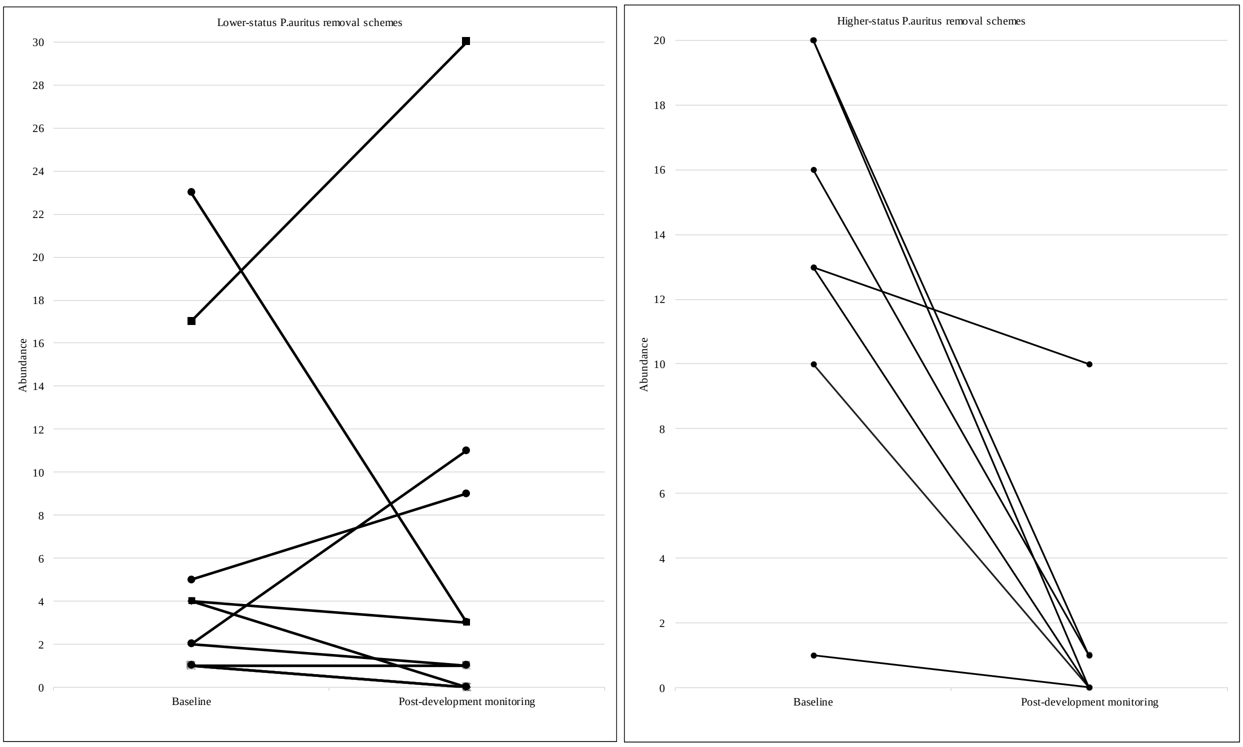



**Figure 5.13**

*Paired dot plots comparing maximum P. auritus counts for roost removal schemes of lower-status (left) and higher-status (right) roosts.*

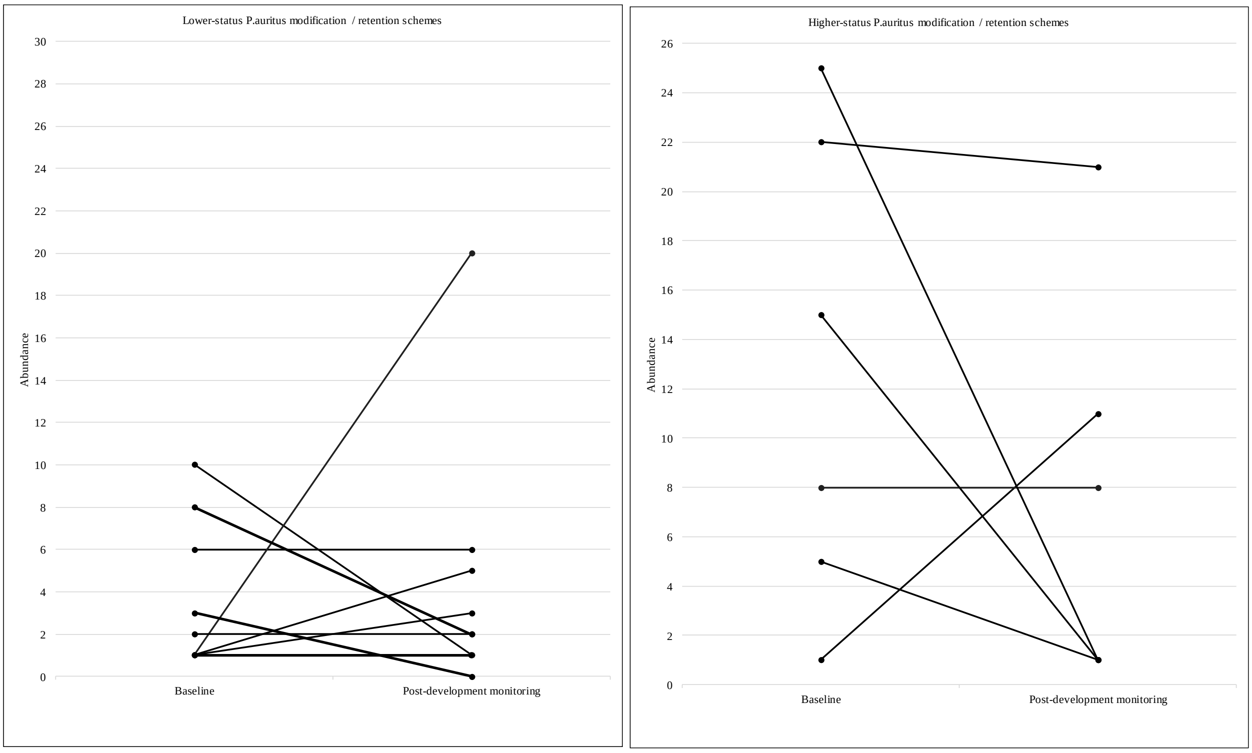
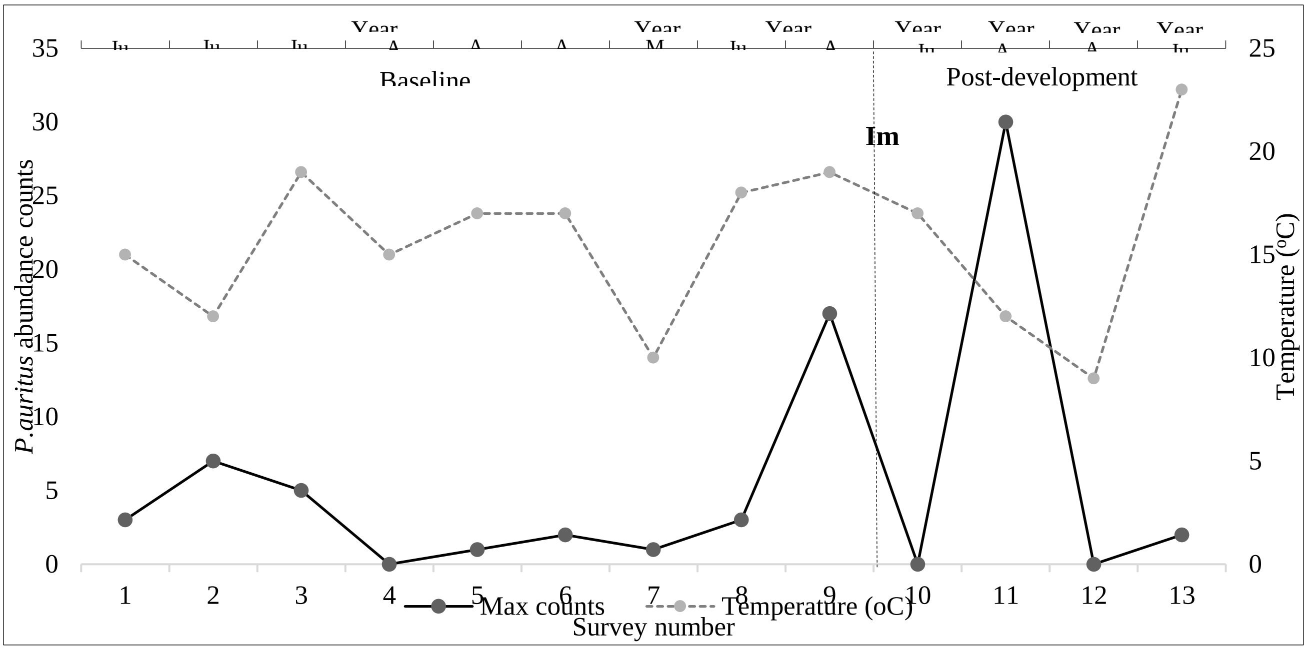



**Figure 5.14**

*Paired dot plots comparing maximum P. auritus counts for roost modification / retention schemes of lower-status (left) and higher-status (right) roosts.*

A single case study involved minor modification work to a *P. auritus* maternity roost. This site was notable because it was subjected to an extended period of night-time roost counts during the baseline stage between 2008-2011, the consultants' monitoring surveys between 2013-2015, and BCT's monitoring work in 2018. Since *P. auritus* maternity colonies are generally considered to be loyal to individual roosts (Entwistle *et al.* 1997 and 2000; Mackintosh, 2016) abundance level data for this ten year period were examined. All surveys took place during the bat active season with each one covering the two primary access points into the roost structure. Abundance levels were observed to fluctuate between zero and 30 bats, both between and within-years, as shown in Figure 5.15.



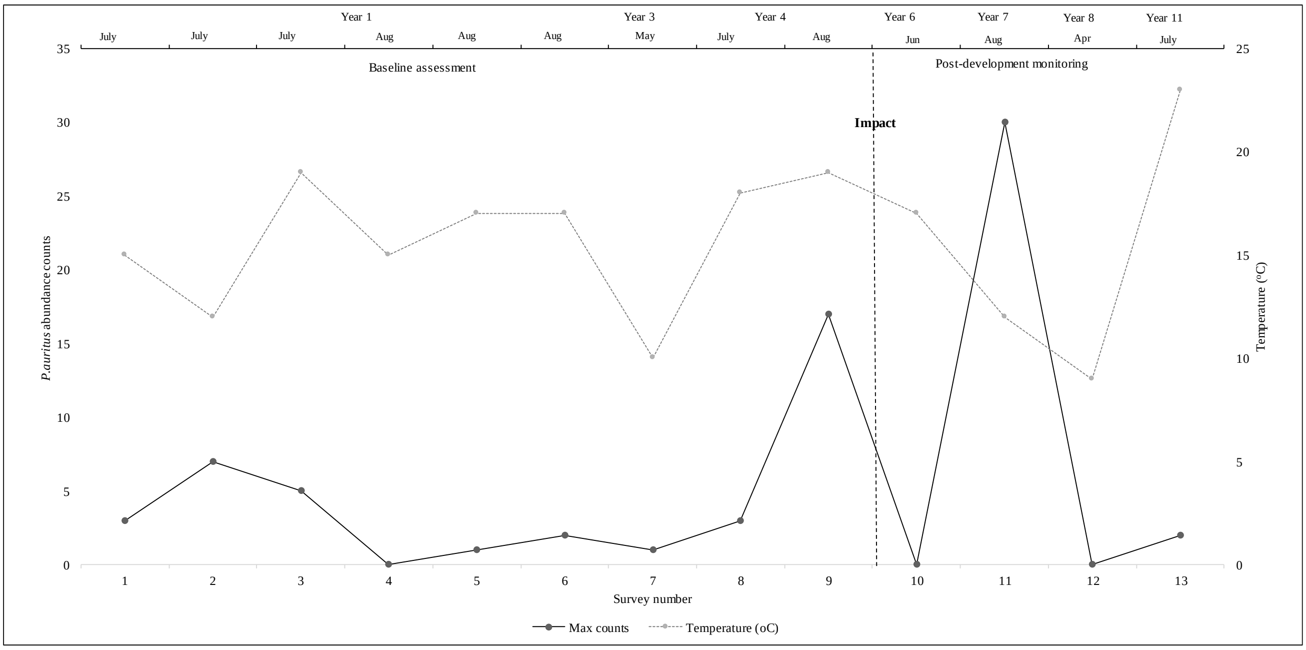




**Figure 5.15**

*Fluctuations in post-development monitoring counts of a P. auritus maternity colony over a ten year period*

## 5.4. Discussion

Since *Pipistrellus* spp. and *Plecotus* spp commonly roost in human-made structures (Entwistle *et al.* 1997; Briggs, 2004), it was not surprising they represented the highest proportion of roosts at the baseline stage and during BCT's monitoring stage.

It was clear that BCT recorded a lower proportion of maternity roosts compared to baseline levels. In particular, the absence of any *Myotis* spp maternity roosts was particularly noticeable, particularly since case studies affecting this group were preferentially selected during the sampling stage. The low frequency of *Myotis* spp roosts inevitably limited our analysis and evaluation of this group in terms of mitigation effectiveness.

Although our findings are reasonably consistent with those reported in previous studies (Briggs, 2004; Waring. 2011; Lintott and Mathews. 2018; Mackintosh, 2016), there are also some key differences.

In terms of species, *Pipistrellus* spp were responsible for the highest proportion of schemes retaining the target bat species, and largely responsible for the 86% of sites which retained bat presence in general.

In terms of abundance, our monitoring data indicated that pre-development roost sizes were maintained for 32% of *P.pipistrellus* and 41% of *P. pygmaeus* schemes. This is a noticeably higher rate compared to the 10% and 7% reported by Lintott and Matthews (2018). This may reflect the increased number of post-development night-time surveys completed or the increased length of time provisions were available before BCT's monitoring assessment. The influence of survey effort and colonisation rates on post-development monitoring results is discussed further in Section 7. Schemes of *Myotis* spp generally displayed the lowest levels of species retention and bat counts in our sample.

It was notable that schemes affecting higher status maternity roosts in our sample were more likely to retain species presence compared to those with lower-status roosts. However, data also indicated that maintaining or increasing the abundance levels was less prevalent for all species including *P.pipistrellus*, and that reductions in bat abundance were inevitably of a higher magnitude for schemes with higher-status roosts. However, the replacement of higher-status colonies with smaller day or night roosts was generally more frequent for all species. Such structures may therefore offer different conditions to those removed. Although unsuitable for maternity use, they may provide cooler environments preferable to bats at other times of the year that may need to conserve energy by entering torpor following periods of insect shortages, prior to hibernation or female bats after lactation (Entwistle *et al.* 1997; Feyerabend and Simon, 2000; Ngamprasertwong *et al.* 2014; Voigt *et al.* 2016).

In contrast to *P.pipistrellus*, the decrease in bat abundance levels for schemes removing *P. pygmaeus* roosts was not significant. Indeed, post-development roost counts for *P. pygmaeus* actually increased in contrast to those of higher-impact *P.pipistrellus* and *P. auritus* schemes which were never maintained. However, considering the small sample size of *P.pygmaeus* maternity colonies in our dataset (n = 2), these cases may be anomalies.

Stone *et al.* (2015a) previously demonstrated that *P.pygmaeus* could adapt to exclusion events by relocating to alternative roosts in the landscape. It was concluded that if such behaviour was shared among *P.pygmaeus* colonies (or other European species), then the presence of alternative roosts may be sufficient to buffer populations against such impacts (Stone *et al.* 2015a). It was considered notable that we recorded several higher-status maternity colonies of both *P.pipistrellus* and *P.pygmaeus* using new provisions at sites where these species were either absent during baseline surveys or recorded in lower numbers. Since it is unlikely that such maternity colonies would have been missed at the baseline stage, it is feasible that these newly installed provisions were drawing bats away from other suitable structures in the landscape – possibly in response to impacts elsewhere. Or that roost provision was a limiting factor and new provision allowed existing roosts to divide.

In terms of impact type, 70% of species-specific mitigation schemes in our dataset were based around roost removal offset by the installation of new compensation roosts. Although removing roosts is the least preferential option in the mitigation hierarchy (Mitchell-Jones, 2004), it must be noted that the selection criteria for this project did not prioritise retained or disturbed roosts, and roost removal schemes are likely to cover a disproportionately higher number of EPS licence applications compared to schemes based around retention / modification, which could have been carried out using un-licensed method statements and may therefore not have been captured by this project.

*P. auritus* schemes based around roost retention, modification or a combination of impacts retained species presence and maintained roost numbers more frequently than schemes where roosts were removed. This is consistent with the findings from previous studies. Indeed, no significant difference between baseline and post-development monitoring counts was found for *P. auritus* schemes involving roost retention and/or modification.

It is possible that limitations in our own understanding of *P. auritus* ecology is limiting the progression of new roost designs. For example, although *P. auritus* roosts are frequently associated with larger, older and more complex roof spaces (Entwistle *et al.* 1997) the underlying reason has not been precisely determined. Entwistle *et al.* (1997) proposed that such selection preferences may be the result of a wider and more complex thermal regime. Similarly, although *P. auritus* and *M. nattereri* have been recorded roost switching in woodland habitats (Smith and Racey, 2019; Bilston, 2014), the movement of *P. auritus* maternity colonies has also been recorded inside building roosts (Ngamprasertwong *et al.* 2014). It has therefore been suggested that the variety of small cavity-type roosts inside loft voids fulfil a range of microclimate requirements (Briggs, 2004), thereby allowing *P. auritus* to replicate the roost-switching habits they exhibit when occupying tree cavities in woodlands (Entwistle *et al.* 2000; Bartonicka and Rehak, 2007). Apart from general loft void presence, our own project results indicated that *P. auritus* were significantly associated with small internal cavity roosts, both during the baseline and post-development monitoring stages.

Likewise, Swift (1997) also recorded that *M. nattereri* maternity colonies generally circled in dark, sheltered areas outside roosts before evening foraging activity and such light-sampling activity is also frequently observed in *P. auritus* (Briggs, 2004). Although generally accepted that maternity colonies of species like *P. auritus* and *M. nattereri* should be provided with a sufficient volume of dark space to facilitate this behaviour (Mitchell-Jones, 2004; Briggs, 2004), there is still uncertainty regarding how dark and how large this space should be. For example, two non-intended provisions with higher *P. auritus* numbers than new bat lofts were recorded from small cavities inside porches that were both small and quite open and exposed. Furthermore, two of the most effective modified voids at retaining *P. auritus* numbers in our sample were those exhibiting relatively high light-levels from skylights. Although the presence of skylights may be associated with warmer internal temperatures, higher light levels may better facilitate light-sampling behaviour compared to voids that are completely dark.

It is clear that more research is needed to fully understand how and why bats like *P. auritus* and *M. nattereri* use loft voids for various activities. The increasing prevalence and steadily reducing costs of technologies like thermal imaging present many opportunities to increase our understanding of their roosting requirements.

Considering that some UK bat species are displaying signs of stabilisation or early signs of recovery from historic declines (BCT, 2019), it may be the case that such site-based mitigation measures are contributing to the FCS of bats at larger scales. For example, reduced levels of human disturbance on bats has been identified as the most important driver for recent population changes in UK bats. However, it is also possible that such outcomes cannot be detected at the site-level using our present survey methods. Nevertheless, considering the current lack of understanding regarding both the short-term and long-term impacts of roost removal on bat survival and reproduction (Stone *et al.* 2013 and 2015a), it would be irresponsible for current site-assessments and policies to assume that such observations are prevalent and widespread in the UK bat species without more information from further research.

## 5.5. Recommendations

- Since both common and soprano pipistrelles were found in higher proportions in small external building cavities, such compensation measures should be prioritised over roof voids, internal cavities and tree-mounted bat boxes for this genus unless baseline assessments indicate otherwise.
- For common pipistrelle bat box schemes, external wall-mounted and wall-integrated bat boxes should be prioritised over tree-mounted ones unless baseline assessments indicate otherwise.
- More research is required into the roosting ecology of all species but in particular the brown long-eared bat, to investigate how bats find new roosts, the efficacy of different access points, microclimatic variability within roosts, light sampling behaviour and the influence of the texture and smell of new materials.
- Since Brown long-eared bats were significantly associated with small internal cavity roosts in this study, mitigation strategies for this species should carefully consider how any such features identified during pre-existing roosts can be replicated in new compensation provisions.

# 6.0. During- and post-construction avoidance and mitigation measures

## 6.1. Background

In terms of planning and development context, 87% (62, n = 71) of BCT's sites required some form of planning consent. Most sites (56%) received consent for minor developments such as domestic re-builds, extensions or renovation work. A smaller proportion (17%) required consent for larger developments like housing estates, mixed-use schemes or smaller commercial sites like schools and care homes. 14% of sites were householder applications for refurbishment work or change-of-use, Listed Building Consent or Faculty Jurisdiction Consent for places of worship. The remaining 13% of sites either required no official planning consent or were covered under Permitted Development rights.

In terms of the sites themselves, 58% (41, n = 71) of BCT's sample were domestic sites including private residences, estates, small-holdings or BandBs (Figure 6.1). Again, a smaller proportion (21%) of sites were commercial, predominantly care homes or buildings associated with the hospitality trade. The remaining sites (21%) comprised places of worship, heritage buildings, schools, universities, community buildings and bridges. Our sample did not include any large-scale infrastructure, engineering or utility developments.

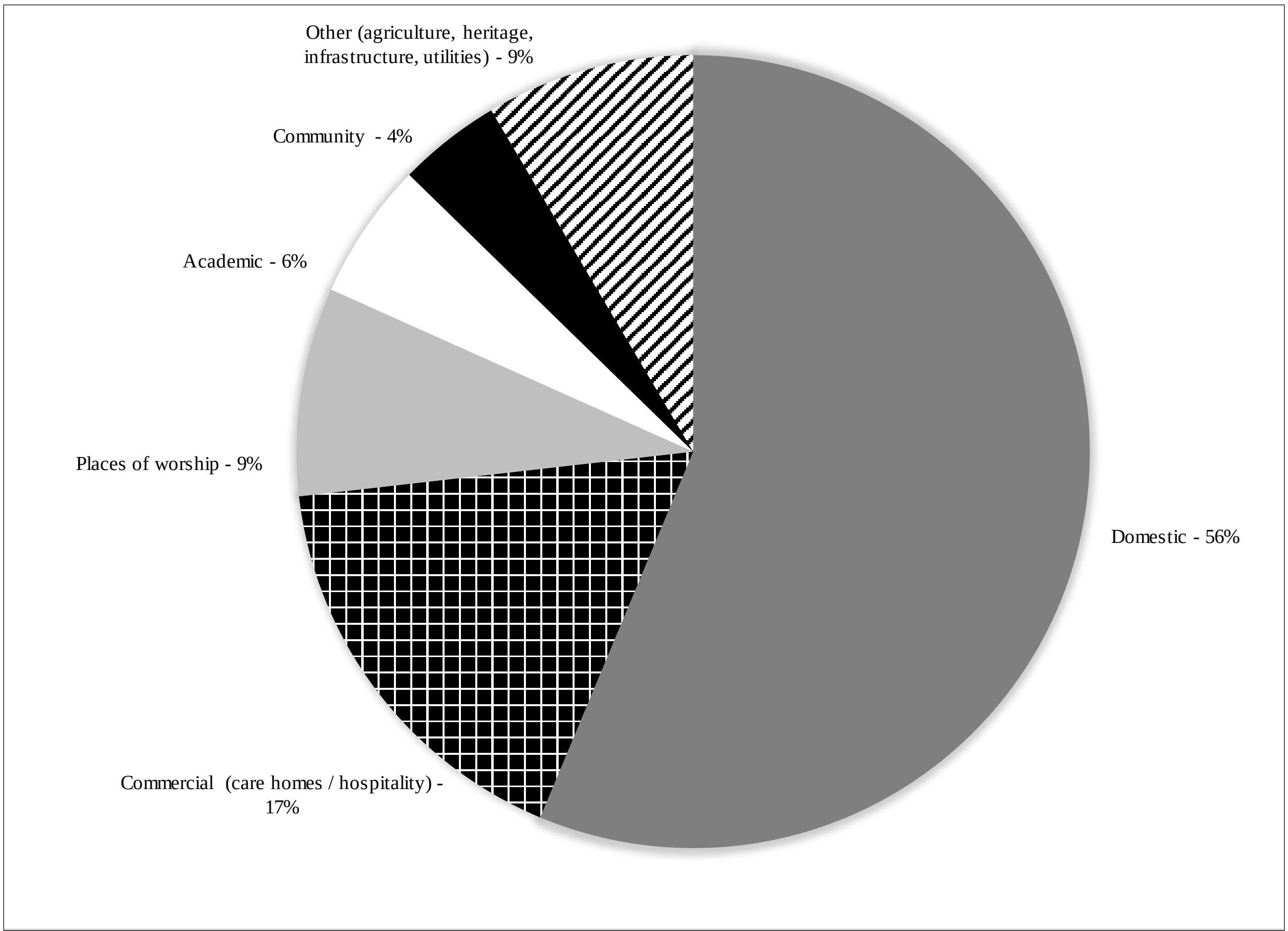



**Figure 6.1:**

*Development types in BCT's Sample*

According to our monitoring surveys, 97% of sites had completed the proposed developments broadly in accordance with the granted planning consent (all approved plans and ecology-related planning conditions were cross-checked) However, two sites had not commenced any development work at the time of BCT's monitoring work. In these instances, the bat roosts had therefore been retained despite certain mitigation measures being installed in advance. In both cases this was because SNCBs had approved EPS licences applications prior to subsequent decisions to cancel or delay development work. Nevertheless, both sites were surveyed in accordance with BCT's methodology and roosts recorded as retained.

Figure 6.2 displays the distribution of years when the licensed bat mitigation work for our sample commenced. This primarily relates to the initial early construction-phase shortly after EPS licences were typically granted and capture / exclusion activities took place. Such activities also typically included pre-works briefings, roost inspections, supervised demolition work and safely moving bats to alternative roost provisions during soft-strip activities 52% (n = 71) of mitigation schemes commenced this work between 2010 and 2012 – 5-8 years before BCT's post-development monitoring work. However, this range was not necessarily when developments were fully completed. This was found to be hugely variable, open to interpretation and a detail frequently not reported or available.

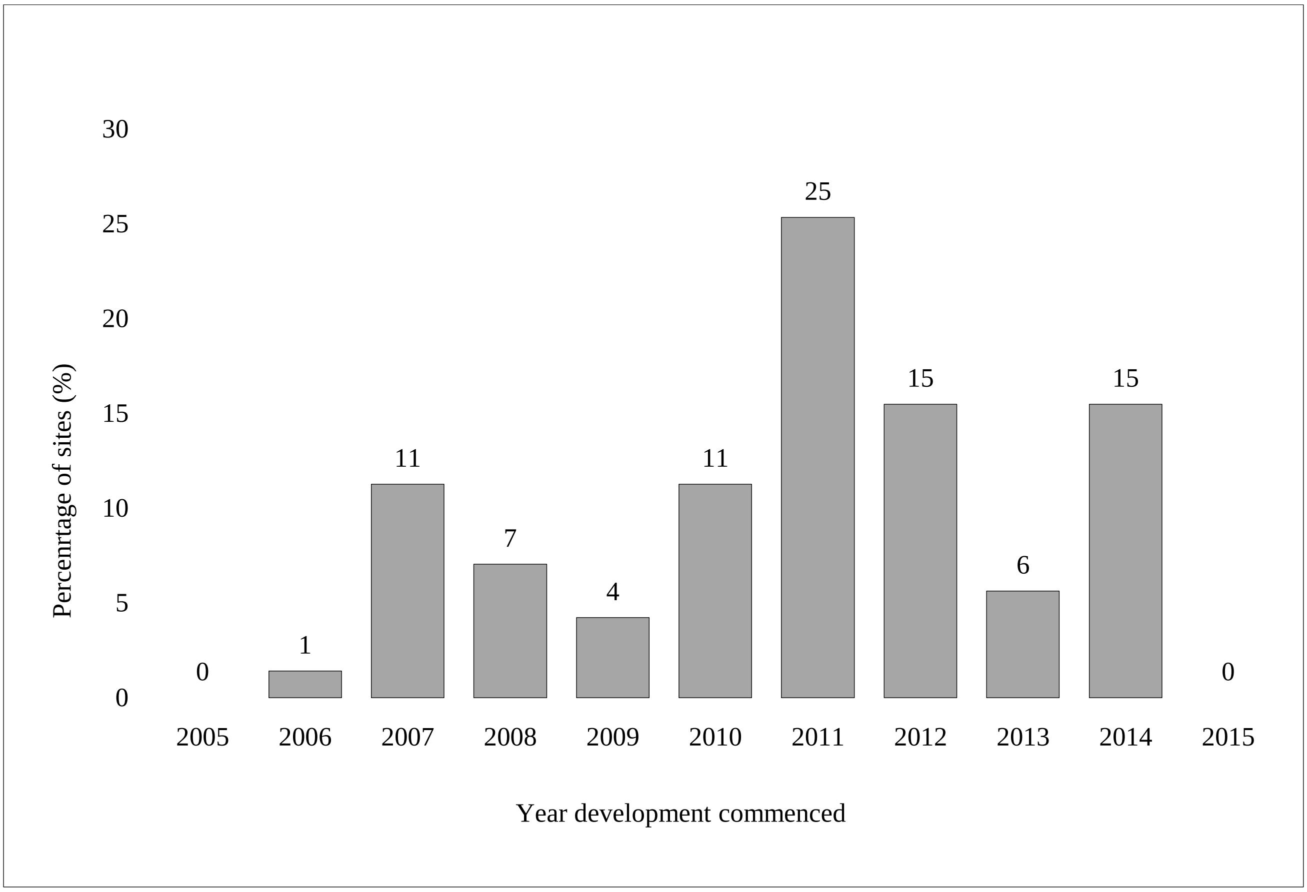



**Figure 6.2:**

*Age range of case studies*

Most method statements proposed specific methods for ensuring that bats were not harmed during construction work. Although this project did not specifically assess these procedures, post-monitoring reports indicated that bats were only moved in 25% of case studies and bat capture rates never exceeded pre-agreed numbers. Therefore, the various timing restrictions, toolbox talks, capture and exclusion techniques and direct supervision work proposed in our sample appeared to be effective at preventing killing or injury. In contrast, the ability of mitigation schemes to retain the presence and abundance of target bat species post-development was mixed.

## 6.2. Methods

### 6.2.1. Construction-phase measures

Although it was not possible to assess their implementation, short term mitigation measures during the construction-process were catalogued for each site because they were often directly or indirectly related to the more long-term measures. This included cataloguing specific details for roost protection, the availability of alternative temporary roosts during construction, specified timings, pre-works briefings, pre-works inspections, capture / exclusion work, soft demolition procedures and protocols to follow if bats were found on site.

### 6.2.2. Post-development processes and safeguards

Details relating to post-development processes were also catalogued and assessed where possible. This primarily related to timings, personnel and details for habitat management measures, roost-condition monitoring, post-development disturbance and managing lighting regimes.

Safeguards were taken as the *mechanisms* for securing commitment and delivery of certain processes rather than the mitigation measures themselves. The presence of such mechanisms did not necessarily guarantee that such measures were implemented so implementation rates of the mitigation measures themselves were used to assess the effectiveness of safeguards.

When method statements were analysed in detail, safeguards were present in a diverse range of measures including construction-phase operations, habitat and lighting measures, new provisions, post-development processes and monitoring. Despite such diversity, we identified two broad types of safeguard: 1) mitigation safeguards for ensuring adherence to mitigation measures during the EPS licence implementation period; and 2) site safeguards for minimising negative impacts to bats caused by ownership or management changes during or after the implementation period.

Safeguards were grouped into three further sub-categories:

- Safeguards embedded into the EPS method statements themselves.
- Planning conditions.
- Other formalised agreements.

## 6.3. Results

### 6.3.1. Managing post-development disturbance and roost condition monitoring

Mitigation was proposed at 39% (n=71) of sites to offset some form of post-development disturbance. Such measures usually involved restrictions for how sites would be managed during the operation phase (68%, n=28). Other measures included restricted access to the roost area by the prohibition of loft void storage (18%), void access hatches being locked, sound-proofing or security fencing.

Some form of roost maintenance / condition monitoring was proposed at 54% of sites. Such safeguards ranged from adequately maintaining access points (8%, n = 38) and replacing / cleaning out bat boxes (11%), to maintaining roof covering materials (5%). However, such safeguards were usually non-specific in method statements and simply referenced the personnel responsible for condition monitoring without describing what it would involve (68%), for example “the owner of the property will be responsible for maintenance of the bat loft”. Only three sites (8%) specified its frequency and duration.

### 6.3.2. Post-development management and condition monitoring

Method statements and other formal agreements (such as S106) included safeguards for 11% of case studies specifying that bats and their roost provisions would be appropriately maintained throughout the licence period. These generally specified: who would be the named personnel responsible for roost maintenance work, that roost access by people was prohibited, that tenants would to be made aware of bat roosts or that maintenance work must comply with licence conditions. Two case studies (25%, n = 8) were not compliant with proposals in method statements. For example, bat information packs were not available to residents at one site during BCT's monitoring visit, although there was no evidence to indicate that the absence of this safeguard had compromised the structural or functional integrity of bat roosts in this instance. A more serious compliance issue was recorded at the second site where third-party contractors had actively taken measures to exclude birds and draughts from the building. This ultimately excluded bats from roosting in the installed roosting provisions.

Method statements proposed remedial measures at 7% of sites if new provisions were considered ineffective following monitoring surveys. Although the exact nature of such measures were understandably not specified so far in advance, indicative actions included clearing access points or moving bat boxes. Only one of the sites proposing remedial actions at the method statement stage actually applied them. This involved the consultancy recommending that bat boxes were moved away from lighting glare, although this had not taken place at the time of BCT's assessment.

However, remedial action was recorded at four other sites despite not originally being proposed. Measures included moving bat boxes, persuading occupants to reduce light levels, adjusting access points and adjusting conditions inside bat lofts. Such actions either took place following a single monitoring visit or during the early stages of a monitoring program, so it was not possible to draw conclusions about the effectiveness of such measures.

Other retrospective remedial measures included one case where the walls and roof of a bat house needed to be re-built, whilst another case involved the ecological consultancy returning to site several times to remove and cover-up MRM in an active bat loft - partially at their own expense.

### 6.3.3. Site safeguards

Post-development site safeguards were recorded at 61% of sites for minimising negative impacts due to ownership changes during or after licence implementation periods. Most safeguards were embedded into method statements (88%, n = 43), either specifying that bat roosts and associated structures would continue to be owned by the licence holder or that new owners were aware of their responsibilities to safeguard roosts. Other formalised agreements provided safeguards for the remaining 12% of sites, including S106 agreements or measures written into site risk registers or property deeds. Only two cases (5%, n = 43) had not fully complied with these safeguards, one of which was where the building ownership had changed. However, a more serious breach had occurred where a retained maternity roost had been excluded from a commercial site by an external utilities company because it conflicted with future access requirements.

### 6.3.5. Project hand-overs

Another issue highlighted by BCT's roost owner interviews (see Section 8) related to a small number of sites where ecologists needed to withdraw from bat mitigation schemes before the developments were completed. Since these were carried out at short notice, roost owners ultimately reported unexpected delays after licences and planning permission had been granted because they struggled to employ competent ecological support. It is therefore possible that the act of withdrawing itself may be less important that the manner it is carried out.

Although using the same ecological personnel throughout the lifetime of a project certainly has advantages (Drayson and Thompson, 2015), it is also important that both clients and ecologists are not locked into long-term arrangements they are unhappy with or cannot commit. The system should be sufficiently robust to allow consultants to withdraw from projects with confidence that bat mitigation will not be compromised without their sole involvement, although it is possible that consultants pull out of projects if their clients ignore their proposals. Likewise, roost owners should retain the right to consider ecological support from third parties if they wish to do so. Therefore, it is important that projects are sufficiently documented so they can be adequately handed over to replacement ecologists if necessary. Further guidance would therefore allow such processes to be more consistent. Roost owners should also be directed to CIEEM's Professional Directory for finding competent ecologists.

### 6.3.6. Long-term safeguards

Although only rarely encountered in this project, a small number of roosts and access points were nonetheless damaged after licence-implementation periods due to failures in post-development safeguards. This was far more frequent at commercial sites where external contractors or site-staff blocked access points to exclude birds and draughts. We recorded at least three instances of potential exclusions; subsequently informing ecologists to seek remediation (it would not be in the public interest to report these cases to the police bearing in mind that the site owners were cooperative and too much time had elapsed since the access points were blocked for a prosecution case to be taken forwards). Safeguards for domestic cases tended to rely on the assumption that licence holders would continue to occupy residences in the long-term. Despite rarely being breached in our sample, the effectiveness of such safeguards relies on the awareness and conscientiousness of individuals. Effective safeguards for raising awareness about bats and staff responsibilities at commercial sites therefore need to be more widely adopted. Although strategically placed warning signs or advisory notices may be an effective strategy in some cases, such measures were only proposed at 17% of sites and implemented at only 3%.

## 6.4. Discussion

SNCBs generally commit to a certain level of compliance monitoring to assess site conditions. However, no such visits were recorded in our case studies, although the recent introduction of bat licensing charges at Natural England may raise their frequency (Natural England, 2019). Nevertheless, realistically the named ecologist on the licence is likely to be in the best position to assess site conditions and direct implementation in most instances. Results from BCT's roost owner interviews (Section 8) indicated that proactive ecological consultants who navigated them through mitigation from start-to-finish accounted for 20% of positive feedback. Such involvement may therefore be a level of service expected and viewed positively in many projects.

## 6.5. Recommendations

- Metadata relating to licensed development work should be systematically collected/collated into a database as part of the licensing process to allow for future analysis of the level of implementation of different provisions.
- The completion date for bat roost mitigation provisions should be recorded by ecological consultants and entered into the relevant database to enable analysis of colonisation times by bats following completion of bat roost mitigation work.
- The specification and application of measures to manage post-construction disturbance, maintain roost structures, safeguard provisions through changes of site ownership or ecologist and safeguard sites in the long-term should be facilitated by the provision of new guidance.
- The licensing system should be sufficiently robust to allow consultants to withdraw from projects with confidence that bat mitigation will not be compromised without their sole involvement. Therefore, it is important that projects are sufficiently documented so they can be adequately handed over to replacement ecologists if necessary.
- Roost owners should retain the right to consider ecological support from third parties if they wish to do so and should be directed to CIEEM's Professional Directory for finding competent ecologists.
- SNCBs and LPAs should be provided with the resources to monitor compliance with licence and planning conditions and carry out enforcement in cases of non-compliance because licence and planning conditions are legally binding.

- The format of licensing documentation should be improved to ensure information is conveyed with clarity to contractors, existing and new site owners, existing and new ecological consultants and post-construction site managers.

# 7.0. Post-construction monitoring

## 7.1. Background

Baseline surveys or repeated surveillance are distinct from monitoring, which has a distinct purpose (Hellawell 1991) and is frequently used to assess whether interventions have been effective over a period of time (Battersby 2010, Collins 2016, CIEEM 2017, Tyldesley 2017). Hellawell (1991) identified three main types of monitoring programs:

1. 'Early warning monitoring' may be used for 'triggering' specified contingencies or remedial measures if ecological objectives have not been achieved (Hellawell 1991, CIEEM 2017, Tyldesley 2017). This is likely to be most relevant in situations where practitioners and decision-makers cannot guarantee the full effectiveness of proposed measures in advance (BSI 2013) or to inform ongoing roost management or remedial operations (Mitchell-Jones 2004).
2. 'Compliance monitoring' may be used for ensuring that projects adhere to agreed obligations such as planning or EPS licence conditions (CIEEM 2017, Tyldesley 2017).
3. 'Effectiveness, or validation, monitoring' may be used to assess whether conservation interventions, policies or legislation are achieving desired outcomes (Hellawell 1991 Battersby 2010, BSI 2013, CIEEM 2017; Tyldesley 2017). More specifically, the 2004 Bat Mitigation Guidelines propose that such monitoring is used to examine whether bat populations at mitigation sites have responded favourably to proposed mitigation measures (Mitchell-Jones 2004).

Monitoring can influence future decisions by either validating the effectiveness of existing policies and interventions, or signalling that such measures must be adapted for achieving conservation goals (Hellawell 1991). Although monitoring mitigation measures that cannot be changed may have no practical merit for those particular schemes, the resulting data may be used to inform future mitigation projects, particularly if novel measures have been used (Mitchell-Jones 2004). If post-development monitoring data is shared more widely then other ecological practitioners and stakeholders can learn from such evidence and inform decision-making, project design and conservation actions (Dickson et al 2017). Post-development monitoring is also important for identifying priority areas for research, demonstrating achievements to clients, legislative obligations, publicity purposes and completing the project 'cycle' (Dickson et al 2017; McDonald-Madden et al 2010; Stone et al 2013). Monitoring therefore has significant capacity to reduce unnecessary project expenditure and increase efficiency (Tyldesley 2017).

Although BCT's Good Practice Guidelines currently inform bat survey work in the profession, they are not intended to guide survey effort for the purposes of post-development monitoring (Collins 2016). However, post-development surveying effort may be an important factor to consider when designing monitoring programs and was reported to be positively associated with mitigation success by Lintott and Mathews (2018). Furthermore, there is currently a level of uncertainty within the profession regarding when post-development monitoring should commence. Hodgkins (2012) concluded that more guidance and research was necessary on this topic. Likewise, Lintott and Matthews (2018) questioned whether monitoring time-frames should be revised to increase the accuracy of pre-and post-development bat number comparisons. This followed a workshop hosted by the Mammal Society Conference in 2017 where audience members argued that, given the relatively short time between mitigation and monitoring, it would be unrealistic to expect bat populations to have returned to pre-construction levels (Lintott and Matthews 2018).

There is some evidence to support these concerns. For example, McAney and Hanniffy (2015) and Poulton (2006) both reported an increased uptake of bat boxes over time, possibly indicating that bats simply need time to find and become accustomed to new roosting opportunities. Although both McAney and Hanniffy (2015) and Tuttle et al (2013) reported that bat boxes were occupied quickly, Teesdale (2006, cited in McAney and Hanniffy 2015) reported that it took several years before boxes were regularly occupied and used by maternity colonies. Other studies reported that colonization rates were variable and often unexplained or inconclusive (Ruczyński and Bartoń 2012; Mackintosh 2016; Lintott and Mathews 2018), possibly because of the difficulty in testing the reason why bats colonised new roosts (Mering and Chambers 2014).

Despite the perceived importance of effectively integrating post-development monitoring into bat mitigation projects (Battersby 2010; Stone *et al* 2013; Moller *et al* 2016), the benefits of such information also need to be considered against the cost (in time and/or money) of acquiring it (McDonald-Madden *et al* 2010). Furthermore, concerns regarding the lack of monitoring in the profession have been raised in previous studies (Drayson and Thompson 2015; McAney and Hanniffy 2015; Lintott and Mathews 2018). Indeed, Lintott and Mathews (2018) reported that an overriding theme in their questionnaire to CIEEM members was that monitoring was often perceived as an unnecessary expense and was relatively easy to dispense with.

Although Stone *et al* (2013) and Lintott and Mathews (2018) assessed the quality and consistency of monitoring and associated reports in licenced bat mitigation projects, the relationship between proposed and applied monitoring is not well documented. As part of BCT's Mitigation Project, empirical evidence was collated from the proposed monitoring prescriptions described in method statements, comparing them to the applied procedures described in post-development monitoring reports.

Section 7 therefore examines the effectiveness and implementation of monitoring programs. it reports on the following project aims:

- To evaluate monitoring implementation rates in BCT's sample by comparing the frequency, duration and survey effort of proposed programs to those applied.
- To investigate the underlying causes behind monitoring implementation rates by examining the possible effects of program intensity, safeguards, planning conditions and EPS expiry dates on monitoring levels.
- To examine the relationship between monitoring survey effort and the apparent success of mitigation schemes.
- To investigate the rate at which bats colonised new roosting provisions and, therefore, whether the duration of monitoring programs was related to apparent scheme success.

## 7.2. Methods

### 7.2.1. Implementation of Monitoring Programs

For sites where monitoring had been proposed, our desk study exercise included obtaining post-development monitoring reports from the digital or paper archives of SNCBs and LPA planning portals. If such reports were absent then ecological consultants, or the companies they worked for at the time, were contacted. If no response was forthcoming after a second attempt, BCT staff requested that roost owners search their own archives prior to our survey visit(s). If no monitoring reports were uncovered during this process then post-development monitoring surveys were recorded as 'cancelled' or 'absent'.

Where monitoring reports were available, procedures for applied monitoring programs were compared to those proposed in the original method statements. Specifically, this included retrieving the following data from method statement and monitoring reports:

- Survey frequency: the number of survey visits.
- Monitoring duration: the length of time (in years) between development completion and monitoring programs being concluded.
- Survey effort: specifically whether programs included night-time survey techniques (i.e. dusk / dawn surveys) as well as daytime-only assessments.
- Case study source: whether case studies were primarily obtained from SNCBs and roost owners, or ecological consultants.
- Presence of safeguards: including those embedded in EPS method statements, planning conditions or other formalised agreements (e.g. S106).
- EPS expiry dates: specifically whether they expired before or after monitoring was completed. It should be noted that Natural England extended the duration of EPS licences in 2010 to account for monitoring work (Stone *et al* 2013).

- Remedial actions undertaken.

### 7.2.2. Effectiveness of Monitoring Programs

#### *7.2.2.1. Survey effort*

BCT recorded the extent of survey effort carried out for each site during the baseline stage, as well as both monitoring stages completed by ecological consultancies and BCT surveyors respectively. Survey effort comprised: 1) the number of daytime assessments undertaken during each period – either internal void inspections or external inspections of small cavities (including bat box checks); and 2) the number of night-time surveys – either dusk or dawn surveys.

Where data was available, BCT also identified whether each active bat roost was recorded by 1) daytime inspection only; 2) night-time surveys only; or 3) roost information had been collected using both techniques.

#### *7.2.2.2. Provision colonisation times*

BCT examined the degree to which bat roost occupancies may have changed over time. This was measured for each roost as the period of time (to the nearest month) between its installation and the earliest point at which bats were either recorded for the first time, or maximum abundance levels were reached.

In order to prepare the relevant information for analysis, the following information was isolated from the rest of the dataset:

- Provisions that had been surveyed during *both* the consultant monitoring stage ('Time-2') and BCT's monitoring stage ('Time-3'). Note that the baseline stage was taken to be 'Time-1'.
- Roost provisions where bats were recorded as present during either the T2 or T3 monitoring stages. Therefore, only provisions that had proven themselves to be effective (to some degree) were included in the assessment.
- Only smaller cavity roosts that had been subjected to night-time surveys during both monitoring stages were included. The basis for this was the significant relationship between the use of night-time survey techniques and the detection rate of these roost types (see below). However, tree and wall-mounted bat boxes were nonetheless included in the assessment because they were generally able to be fully inspected using day-time assessments.
- Only new or non-intended roosting provisions were included, as opposed to retained or modified structures, where bats would be predicted to return to such structures sooner.

Survey results were included for each T2 inspection, but combined where more than one visit was undertaken within a 12-month period to account for short-term bat abundance fluctuations. Overall, 133 roosts from 27 sites were subjected to repeated measures analysis with the presence / absence of bats used as the outcome variable. BCT used a binomial GLMM to fit a logistic regression model, with each site used as a random term.

## 7.3. Results

### 7.3.1. Implementation of Monitoring Programs

#### *7.3.1.1. Monitoring implementation rates*

Post-development monitoring surveys were proposed in 93% (n = 71) of method statements. In terms of gross implementation rates, monitoring was completed at 38% of sites, 24% of sites had monitoring that was partially completed with reduced frequencies, duration or survey effort, and 31% of sites cancelled the monitoring entirely (Figure 7.1).

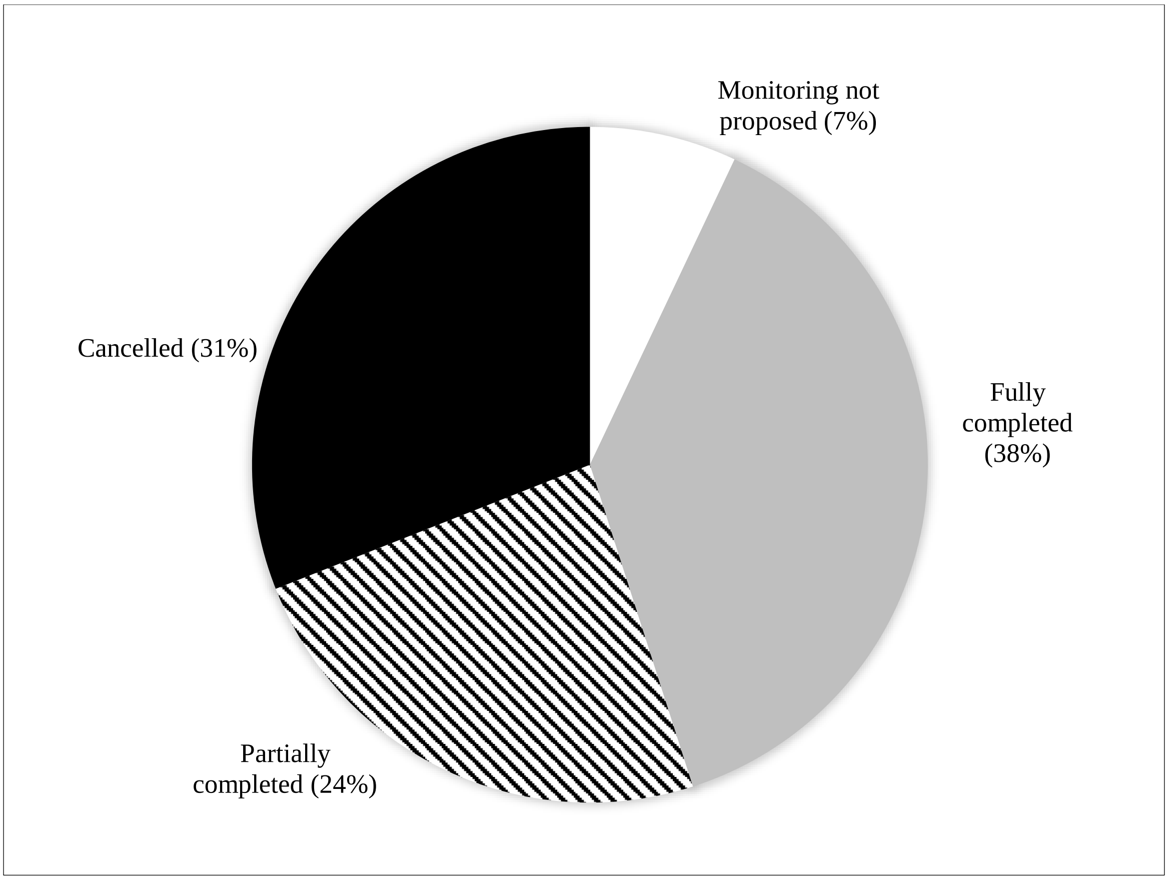



**Figure 7.1**

*Implementation of proposed monitoring programs*

*7.3.1.2. Survey Frequency*

In terms of frequency, 86% (n = 66) of programs typically proposed between 1-3 surveys. Only 14% of programs proposed more than this, most of which (78%, n = 9) belonged to schemes impacting maternity or hibernation roosts. Figure 7.2 displays the frequency of proposed and applied monitoring programs.

Generally, our results indicated that programs proposing a single monitoring survey had higher implementation rates than those proposing two or three, with 70% (n = 17) of single-visit programs following through with the proposed number of surveys. In contrast, only 38% (n = 40) of programs proposing 2-3 visits completed the proposed number of visits, with 23% completing less than proposed and 40% cancelled altogether. Indeed, it was clear that as the number of proposed visits increased from one to three, the proportion implementing less or no surveys increased from 29% (n = 17) for single visit programs, 52% (n = 25) for 2-visit programs and 80% (n = 15) for 3-visit programs.

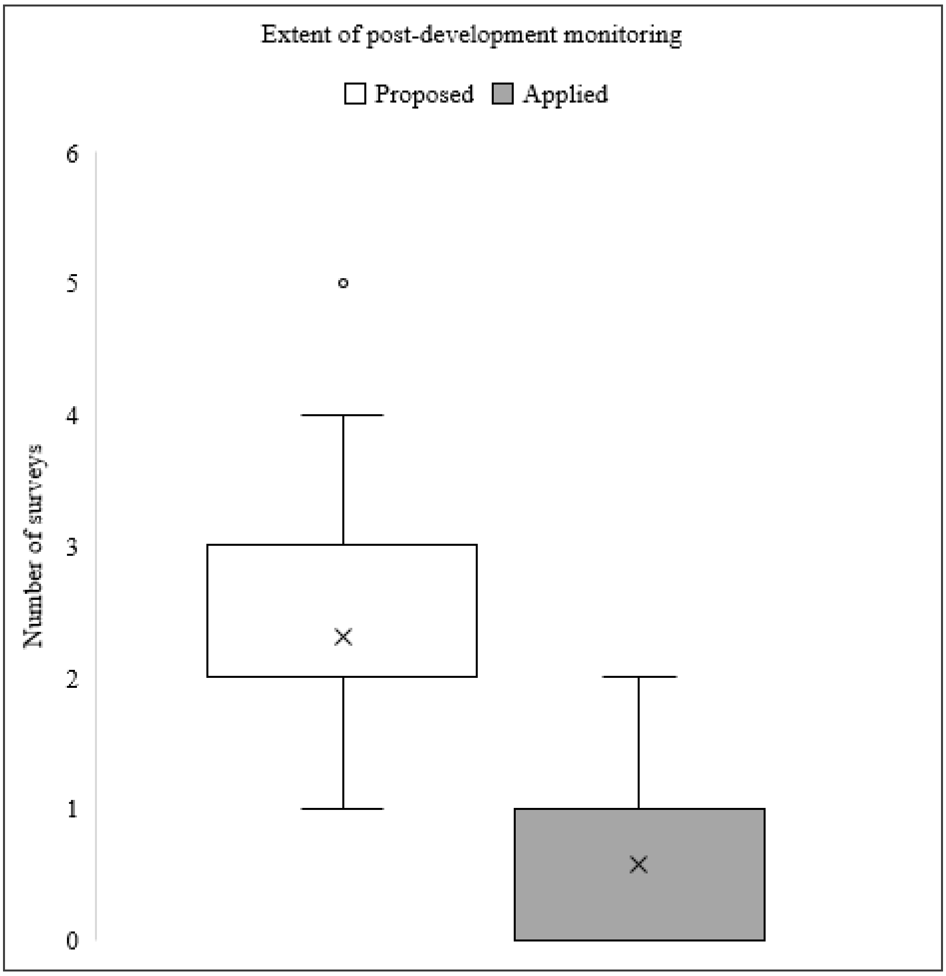



**Figure 7.2**

*Frequency of post-development surveys proposed and applied during the consultant-monitoring stage*

*7.3.1.3. Monitoring Duration*

In terms of duration, most programs (76%, n = 66) proposed that surveys be repeated annually for 1-3 years. Indeed, almost half of these (46%, n = 50) proposed monitoring durations of one year. A smaller proportion proposed monitoring durations over 3 years (23%, n = 50). Only a third of these longer-duration schemes (33%, n=15) featured maternity roosts, the remaining cases featuring smaller day roosts. This highlights that monitoring programs for higher-impact schemes typically had an increased number of survey visits than lower-impact schemes, but did not typically extend beyond three years.

The proportion of monitoring programs concluding prematurely by at least one year or being cancelled altogether increased from 30% (n = 23) for single-year programs, 47% (n = 17) for two-year programs, and 70% (n = 10) for three-year programs. However, all two- and three-year programs were associated with higher survey frequencies and no single-survey program proposed monitoring durations beyond one year. Furthermore, no partially-compliant monitoring program that was concluded prematurely didn't also include a reduced number of survey visits. Indeed, 33% (n = 12) of the implemented single-visit programs were concluded at least one year later than scheduled. This suggests that survey frequency is perhaps more of a barrier to monitoring implementation than duration.

*7.3.1.4. Survey Effort*

In terms of survey effort, most programs (55%, n = 66) proposed some level of night-time monitoring work, with a smaller number proposing daytime-only assessments (27%). When examining monitoring programs with proposals for both daytime and night-time surveys, only 16% (n = 36) excluded the night-time element but continued with the daytime survey work. A larger proportion of these monitoring programs were cancelled altogether (39%, n = 36). This is a higher cancellation-rate compared to daytime-only programs (22%, n = 18). Perhaps surprisingly, 42% (n = 66) of programs completed at least one dusk / dawn survey when such techniques had not been specified in method statements.

### 7.3.2. Examination of influences on implementation

#### *7.3.2.1. Case Study Source*

The 22 cancelled monitoring programs were assessed in more detail by examining how the case studies were originally received by BCT. Significantly less case studies with cancelled monitoring programs were received directly from consultants or CIEEM members (36%, n = 22) compared to those received from SNCBs and roost owners (64%). This is understandable since BCT initially targeted ecological consultants by sharing resources with CIEEM as part of Lintott and Matthews' (2018) mitigation project, for which the presence of post-development monitoring reports was a requirement for inclusion. However, this also suggests that BCT's sample may have been biased in favour of sites receiving uncharacteristically high levels of monitoring. Indeed, 81% (n = 43) of monitoring programs received from consultants and CIEEM members were fully or partially compliant. Therefore, the lower monitoring implementation rates for cases received from SNCBs and roost owners (39%, n = 23) may more accurately reflect national monitoring rates in England and Wales between 2006 and 2014.

#### *7.3.2.2. Planning conditions and other safeguards*

Safeguards for delivering post-development monitoring were proposed at 34% (n = 66) of sites. Most of these (77%, n = 24) were formalised assurances embedded in method statements rather than planning conditions or S106 agreements. Such safeguards included statements of commitments to the monitoring program (for example, 'the licence holder will ensure the consultant is appointed to complete monitoring work'), an acknowledgement of legal responsibility (for example, 'the licence holder is fully aware of the requirement to undertake monitoring work') and financial assurances (for example, 'a purchase order will be raised before the end of project so the ecologist can complete monitoring'). Monitoring programs were cancelled in 31% of these cases.

Only 8% of cases received formal planning conditions directly relating to monitoring effort. These either specified that 1) monitoring effort would be agreed with LPAs following planning permission and implemented accordingly; 2) that monitoring reports were provided to LPAs following monitoring; or 3) both. Despite their presence, 67% (n = 5) of these monitoring programs were cancelled.

Overall, when assessed in isolation, 32% (n = 24) of programs with specific monitoring safeguards were completed as specified, 24% being partially completed and 44% cancelled altogether. Therefore, the implementation rate for these programs was even less than the average (41%, 26% and 33% respectively). This suggests that such safeguards had little-to-no effect on monitoring implementation rates.

#### *7.3.2.3. EPS Expiration Dates*

As part of our desk-study exercise, we also examined whether EPS licence expiration dates may influence monitoring implementation rates. Although this information was unknown in several cases, monitoring generally commenced more frequently when the licence expired after the proposed completion date (88%, n = 59) compared to when it expired prematurely (63%). Although this suggests that extending the EPS expiration date beyond the monitoring period may have been somewhat effective at increasing implementation rates, this is not necessarily the case. 94% of the programs with extended EPS expiry dates (n=16) were either received directly from consultants / CIEEM members, or they provided the method statements. Since most un-monitored sites were received by SNCBs and / or roost owners (see above), it is possible that the case study source was influencing these higher implementation-rates rather than extended EPS expiry dates.

*7.3.2.4. Remedial Actions*

Only 14% (n = 66) of monitoring programs specified that results would trigger some form of action or response. Triggered actions for four of these programs (44%, n = 9) involved follow-up surveys to more confidently establish whether bats were using provisions. The remaining five programs involved some form of remedial action. Although the exact nature of such measures were understandably not specified so far in advance, remedial actions ultimately performed included: moving bat boxes away from lighting glare; adjusting access points; improving internal conditions inside bat lofts; and removing MRMs.

## 7.3.3. Effectiveness of Monitoring Programs

*7.3.3.1. Survey effort*

Figure 7.3 displays the overall number of roosts recorded during the baseline and each of the two post-development monitoring stages. Figure 7.4 shows the number of daytime and night-time surveys completed at each stage.

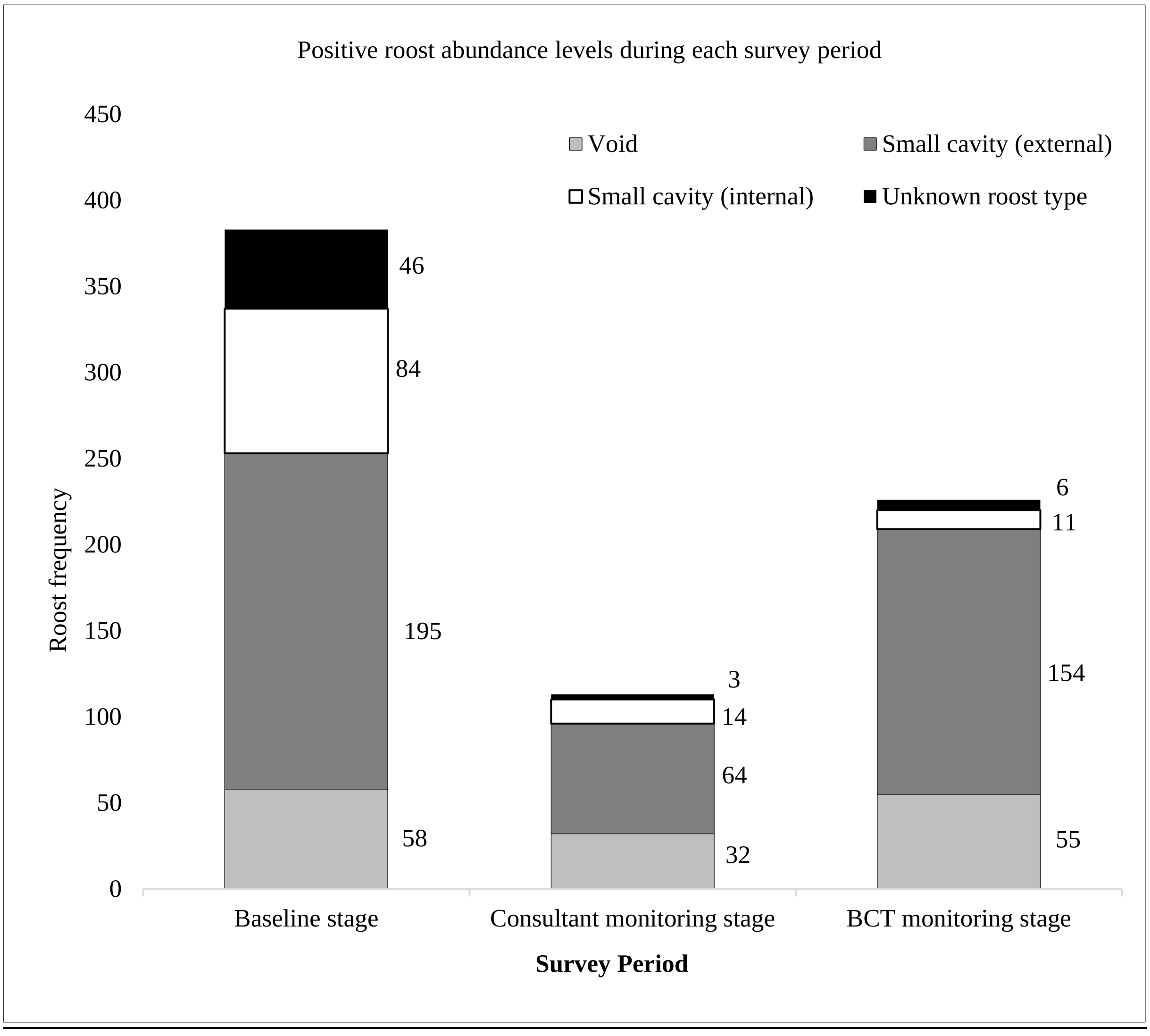



**Figure 7.3**

*Number of broad roost types recorded during baseline (T1), consultant (T2) and BCT monitoring (T3) stages*

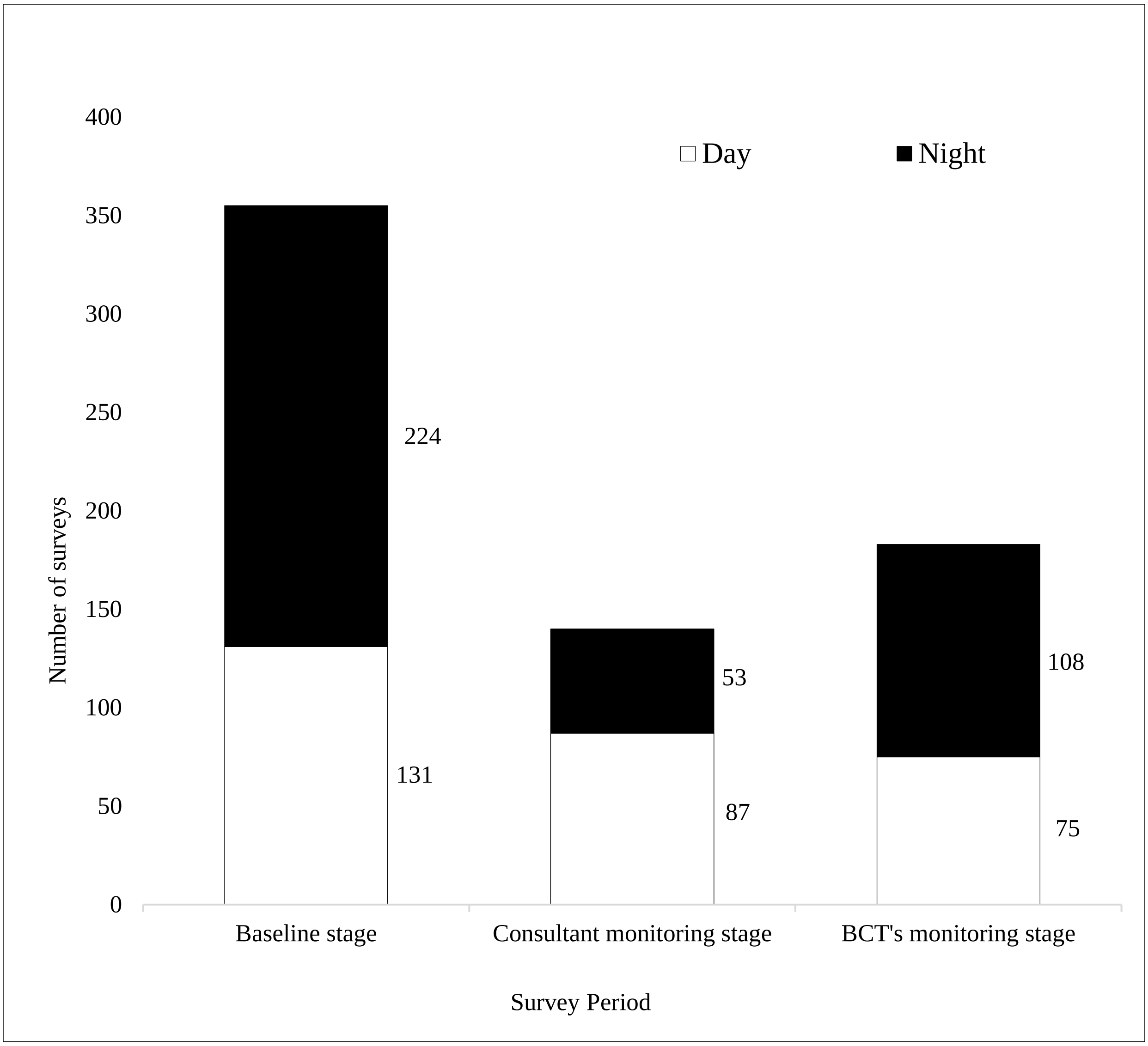



**Figure 7.4**

*Number of roosts recorded using daytime and nigh-time survey techniques*

It was evident that Figures 7.3 and 7.4 showed a relationship between the frequencies of active roosts recorded at each stage and the number of surveys completed. Although the number of night-time visits exceeded that of day time visits during baseline and BCT's monitoring stage, the reverse was the case during the consultant monitoring stage.

Figure 7.5 shows the degree to which daytime and / or night-time survey techniques were used to detect different roost categories in BCT's sample. The results from all three survey stages (baseline, consultant and BCT monitoring stages) were combined for this assessment.

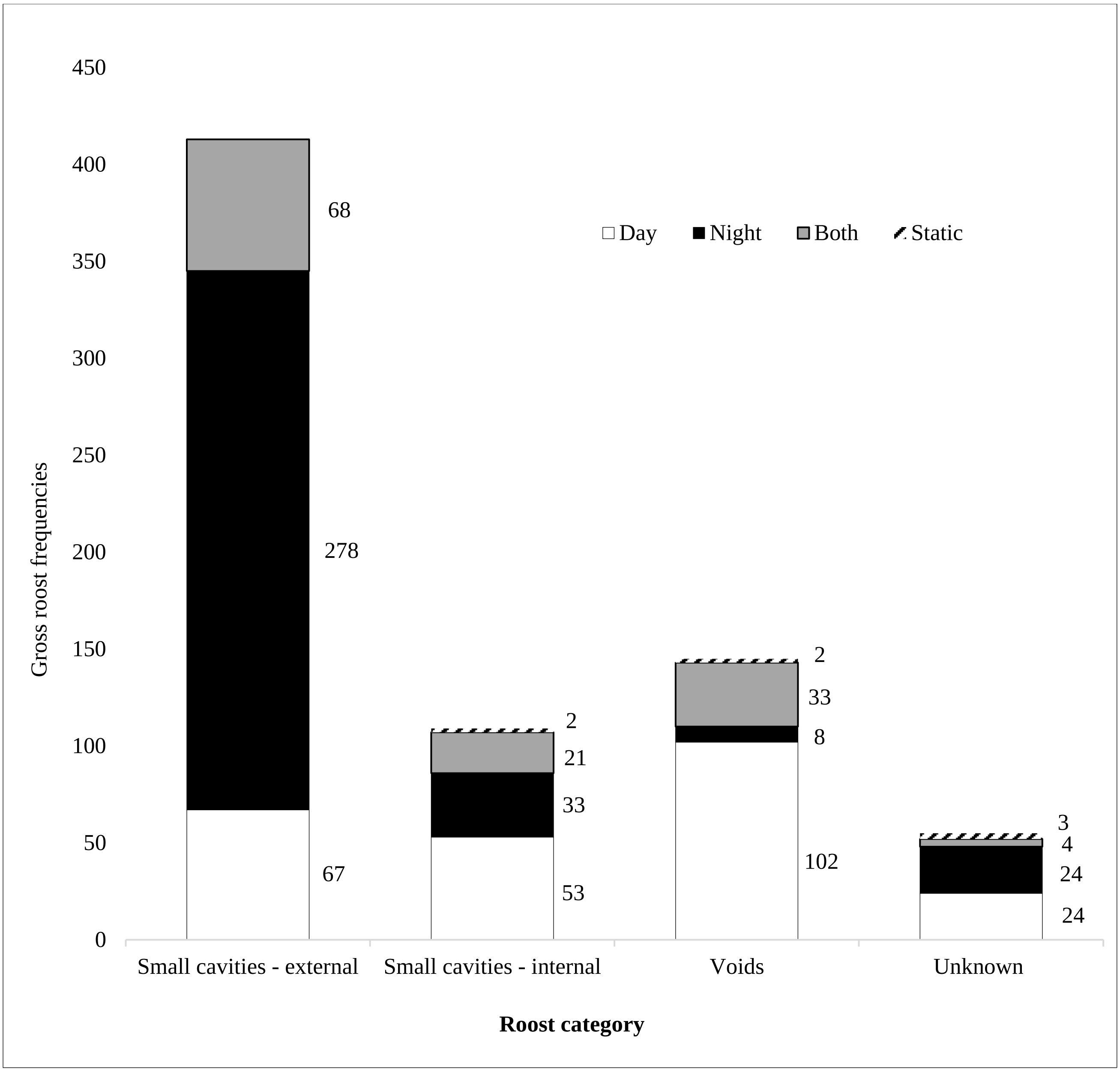



**Figure 7.5**

*Number of roosts recorded using daytime and nigh-time survey techniques*

Although the GLMM model demonstrated a small correlation between the number of day time surveys completed and frequency of conservation outcomes met at sites, it was not strong or statistically significant (F = 2.57 with 1 and 91 d.f., p = 0.113). However, its correlation with night-time survey numbers was both stronger and statistically significant (F = 9.16 with 1 and 108 d.f., p = 0.003**). However, improvement in the number of conservation outcomes tended to level off when the number of assessments exceeded three (F = 3.64 with 1 and 86 d.f., p = 0.060), possibly indicating that increasing the number of monitoring surveys beyond three may result in diminishing returns for detecting bat occupancy rates in new roost provisions.

Results indicated that night-time survey techniques were consistently more effective than daytime techniques at detecting bats that roosted in smaller external cavity-type roosts during all three survey stages (80%, 63% and 53% respectively). The opposite was the case for internal smaller-cavity roosts and voids, which consistently relied on daytime techniques or a combination of both daytime and night-time techniques to detect bats compared to external small cavities.

In general, it was found that the more survey effort carried out on sites and structures, the more bats and roosts were likely to be found. Sites with a disproportionately high volume of baseline data compared to post-development monitoring were therefore less likely to be considered successful compared to sites with good quality monitoring data but poor baseline data.

*7.3.3.2. Provision colonisation times*

Figure 7.6 displays the time-frame by which active bat roosts were first identified or characterised during the T2 and T3 monitoring stages. This relates to sites where roosts were present during either the consultant (T2) or BCT's (T3) monitoring stages, but excluding any identified by BCT only that were not present or had not been surveyed during the T2 stage. Overall, 104 bat roosts were active during the consultant monitoring stage.

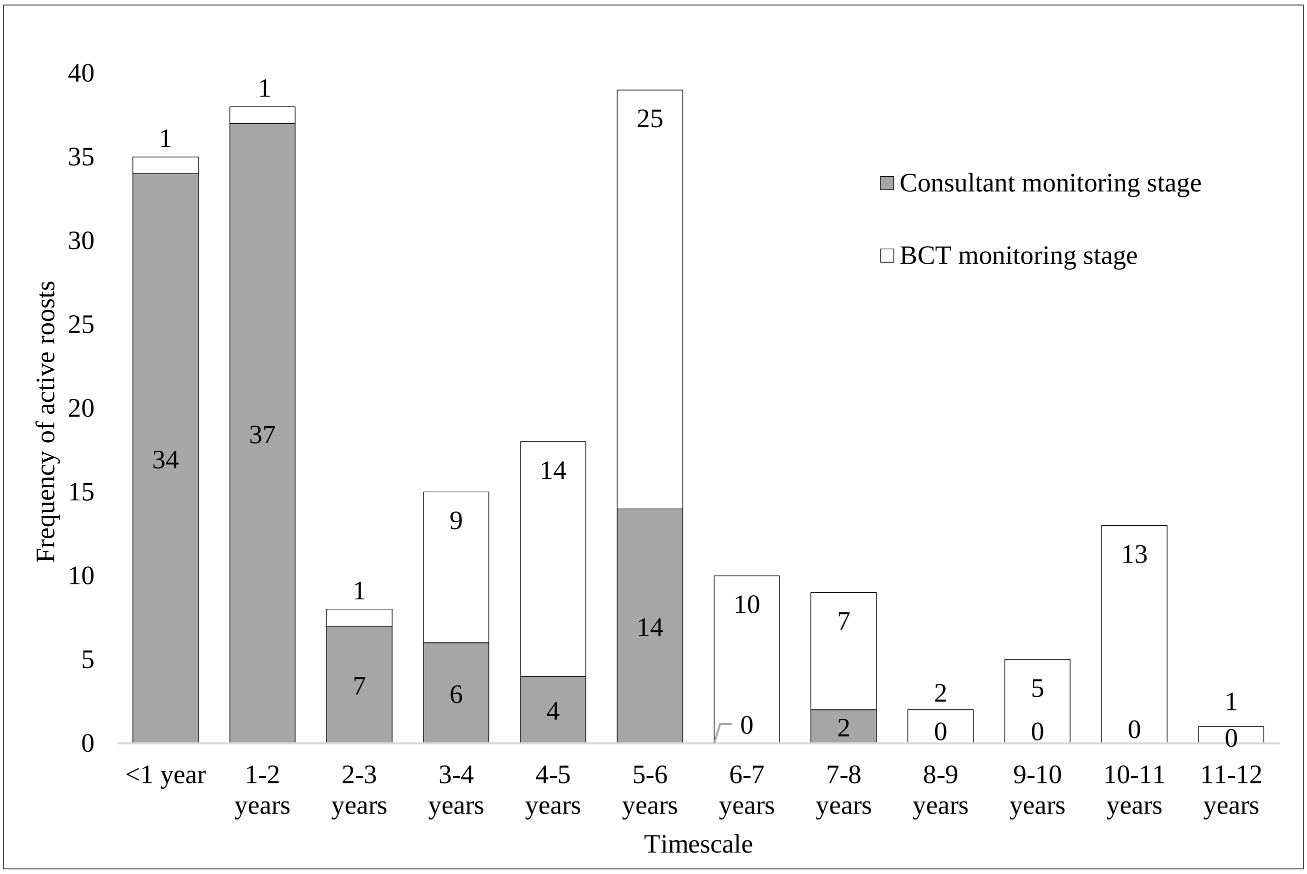



**Figure 7.6**

*Number of years between roost installation and bat presence being established*

Results indicated that 71 of the active roosts identified during the T2 monitoring stage (68%, n = 104) had been characterised within two years of being installed. Indeed, most active roosts were either recorded during the first two years after installation, or between 5-6 years afterwards. This may be a function of survey effort, since 98% of roosts identified / categorised in the first 2 years after installation were recorded during the consultant monitoring stage. Most of these roosts (52 or 73%) were present at sites where consultant monitoring was completed within two years. Of the 39 roosts identified 5-6 years after installation, 82% of these were recorded during BCT's monitoring stage. Since 48% of BCT's sample of case studies were completed between 2011-2013, BCT surveyors therefore monitored a disproportionately high number of sites 5-6 years after roosts had been installed.

To account for such variations in monitoring frequency and different time periods, we separated the repeated-measures data from the T2 and T3 stages into groups according to the length of time between roost installation and monitoring. The first group was reserved for roosts surveyed less than 6 months after installation, while all other survey visits were grouped into subsequent 12-month periods. A log-linear binomial GLMM model revealed that the percentage of active bat roosts present between annual groups was highly significant ($F = 5.37$ with 10 and 358, $p = < 0.001$***). The model reported this percentage to increase over time but level-off after approximately 60 months (five years). However, the pattern was less distinct after this time period. Random effects at the site-level and differing time periods of observation, may therefore have caused the model's predicted values to be higher than those observed. Due to uncertainty in the relationship, a second polynomial GLMM model with site as a fixed factor was examined and gave a slightly different pattern. Both are displayed in Figure 7.7.

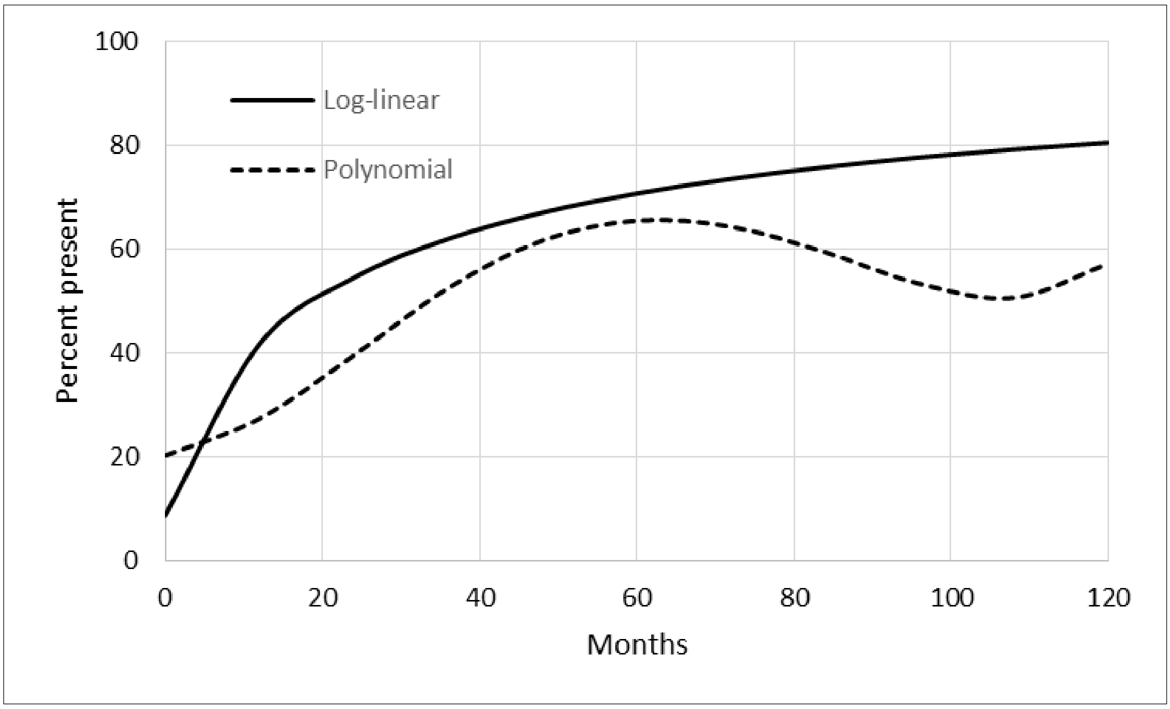



**Figure 7.7**

*Predicted relationship between time (measured in months) and gross bat roost occupancy rate*

Results indicated that overall roost occupancy rates increased over time, but this pattern was only reliable up to approximately five years. Analysis using the GLMM model suggested that increasing the monitoring duration period beyond this point may result in diminishing returns for detecting bat occupancy levels in newly-installed roosting provisions. In particular, analysis demonstrated that bats started occupying new provisions very soon (within six months) after installation, and that most effective provisions had become occupied within two years.

## 7.4. Discussion

### 7.4.1. Summary

Overall, the implementation of post-development monitoring programs was noticeably lower compared to the installation of long-term roosting provisions (Section 3). Indeed, there was a large discrepancy between the monitoring implementation rates of programs received by ecological consultants and CIEEM members (81% of programs were fully or partially completed) compared to those received exclusively from roost owners and SNCBs (39%). There are several possible reasons for this, including the fact that consultants were initially targeted by CIEEM as part of Lintott and Matthews' (2018) mitigation project where completed monitoring programs were a requirement for inclusion in the study. Case studies with completed monitoring programs were also more likely to have been longer-term projects with more extensive paper trails and higher levels of involvement by consultants, all of which may increase the likelihood of selection. Nevertheless, this does suggest that such cases may have received uncharacteristically high monitoring rates, and that the lower implementation rates recorded in cases received from SNCBs and roost owners may more accurately represent national monitoring rates as a whole.

### 7.4.2. Barriers to Monitoring Implementation

#### *7.4.2.1. Cost*

Evidence from this study indicates that survey frequency (i.e. the number of monitoring visits) appears to be the most noticeable barrier to program completion. Generally, programs with two or more survey visits, as well as those including some level of night-time survey effort, were more likely to be cancelled or only partially completed. Both of these factors were more influential than monitoring duration in our sample. Since higher levels of survey frequency and night-time effort both increase the cost of monitoring programs, at first glance this would appear to be the most likely explanation. Cost has also been highlighted as a potentially important factor in other studies (McAney and Hanniffy 2015; Lintott and Mathews 2018).

However, although few in the profession are likely to argue against cost being at least a contributory factor, it is debatable whether such low monitoring rates are purely due to the inability of roost owners to financially commit to such work. Generally, the costs incurred by roost owners / developers on typical bat mitigation schemes can be divided into the following activities 1) baseline assessments; 2) the EPS licence application; 3) short-term mitigation activities before / during construction; 4) the provision of long-term roost / habitat features; and 5) post-development processes (for example, monitoring). Although the degree to which expenditure is divided amongst these five phases will differ between projects, the cost of implementing monitoring programs is unlikely to be significantly more compared to other phases.

Of course, monitoring is frequently the last project activity to commence. Therefore, it is plausible that earlier activities could have a cumulative effect on project budgets to the point that monitoring costs simply cannot be secured. However, this was not reported by any of the roost owners or developers interviewed in our sample. Indeed, one case study involved the developer going into liquidation shortly before construction was complete, yet monitoring still commenced. If low monitoring rates are motivated more by an unwillingness to pay, rather than an inability to pay, then the underlying causes are likely to be more complex than cost alone.

#### *7.4.2.2. Lack of enforcement*

Monitoring safeguards, such as informal statements of intent and more formal planning conditions, appeared to have very little influence on the implementation of such programs. Likewise, although the true effect of extended EPS expiry dates on monitoring rates was not clear from BCT's data set, Natural England (pers. comm) are not confident that this measure introduced in 2010 significantly improved the issue. Since there was no clear difference in monitoring rates between case studies with safeguards and those without, it is feasible that roost owners / licence holders may have been aware of their monitoring obligations but did not take them seriously. The ineffectiveness of such safeguards must therefore be at least partially due to the absence of active enforcement measures by SNCBs and LPAs – ultimately caused by a significant lack of resources (Lintott and Mathews 2018). However, since this lack of enforcement is also inherent in other areas of the licenced mitigation process receiving higher implementation rates, this suggests that lack of enforcement alone is also unlikely to be the only explanation.

#### *7.4.2.3. Poor communication and lack of workflow*

Since it is the responsibility of licence holders to initiate the monitoring process, we must conclude that roost owners were either not aware of this obligation or did not take it seriously enough to trigger it. Following BCT's interview process with roost owners, it was clear that several individuals were genuinely not aware that post-development monitoring was a requirement at all, while others were vaguely aware but assumed it was the responsibility of SNCBs or ecological consultants to initiate the program. Although this project did not have access to all paper trails for examining how monitoring programs were triggered, when they were available it was generally clear that such work was triggered in an ad-hoc manner, relying more on the actions of certain conscientious individuals rather than adhering to an organised system of working. In cases where monitoring had been cancelled, it was certainly apparent that there was a level of diligence and systematic communication amongst consultants, LPAs, SNCBs and roost owners in other project phases that was absent when it came to monitoring.

#### *7.4.2.4. Lack of confidence in the value of monitoring programs*

The contrast between implementation rates of monitoring programs with other aspects of the licence process may also be explained by insufficient incentives to see the process through. The requirement for receiving planning permission and / or EPS licences before developments can proceed is a very clear incentivised target for roost owners. Likewise, once EPS licences have been granted, short-term mitigation processes such as soft demolition and capture-exclusion work are specifically designed to prevent the killing and injury of bats. The intention is therefore clear-cut and explicit, and even those with less-than neutral attitudes towards bats may react negatively to this type of impact if the process fails. Furthermore, the purpose of providing tangible long-term roosting or habitat features is also rather self-evident. However, the process of monitoring such provisions may be rather more nebulous to roost owners. Since such a small proportion of monitoring programs specified that results would trigger some form of remedial action, their primary purpose was presumably for learning and evaluation. However, if such provisions were confidently recommended by professional bat workers and subsequently approved by LPAs and SNCBs, such mitigation is therefore being framed throughout the process that there is little doubt over their effectiveness – in which case roost owners may legitimately question why monitoring is necessary.

Data recorded from these site-level monitoring surveys do not currently feed into a wider learning and evaluation process. Assuming that roost owners are at least somewhat aware of this, unless they hold a particularly keen interest in following up effectiveness themselves, the only stakeholders likely to benefit from this activity are the ecological consultants collecting the data, since they can subsequently integrate any lessons learned into future projects or their own professional development. In some circumstances there may even be some hesitation on the part of consultants whether the long-term value of monitoring data genuinely justifies the financial investment by their clients, particularly if their working relationship has become strained during long-term projects or there is a concern (genuine or not) that roost owner attitudes towards bat conservation may deteriorate with further work. Indeed, the main drive for completing monitoring programs appears to be the fulfilment of licence reporting requirements. However, in the absence of active enforcement measures, evidence suggests that this alone is not a sufficiently compelling incentive for motivating stakeholders to execute monitoring programs.

### 7.4.3. Opportunities for improving monitoring implementation

It is acknowledged that actively enforcing monitoring implementation by LPAs and SNCBs would require additional resources. However, we believe there are several opportunities for improving implementation rates without the need for such enforcement measures.

#### *7.4.3.1. Developing a higher-level monitoring process*

If an active framework was put in place, data recorded during site-based monitoring programs could potentially be used to generate evidence for higher-level monitoring schemes. This would not only provide a powerful learning and evaluation tool, but also serve as a positive incentive for stakeholders to commit to such work. Even if there was some uncertainty regarding the effectiveness of such an approach, such a framework would nonetheless provide transparency to the rationale behind site-level monitoring programs and how the data would be used.

It must be acknowledged that if roost owners are to be incentivised by such an approach, there would need to be a clear understanding that certain evidence gaps continue to exist in the area of bat mitigation, that their mitigation scheme is part of a wider conservation issue and that it is important to feed evidence back into the cycle to inform future projects. This would inevitably require a cultural shift in how certain aspects of bat mitigation are communicated to roost owners.

#### *7.4.3.2. More robust monitoring guidance*

General information relating to the design of bat mitigation monitoring programs is currently limited to a brief section of the Bat Mitigation Guidelines (Mitchell-Jones 2004). Therefore, developing a more detailed set of post-development monitoring guidelines would not only enable practitioners to use a more standardised approach, but also make the process more transparent, consistent and predictable for stakeholders. It is suggested that such guidance should include the following:

- A robust rationale for post-development monitoring surveys, including the different reasons for data collection for helping practitioners and decision-makers design and review effective programs.
- Some guidance for performing a cost / benefit analysis (or similar framework) of monitoring to allow practitioners to make an explicit and transparent decision about its requirement for certain projects, and how to design schemes that are proportionate to the nature, location and size of bat mitigation projects (Drayson and Thompson 2015) especially if there is a genuine concern that its value to bat conservation may not justify the financial investment (McDonald-Madden *et al* 2010).
- More detailed best-practice guidelines for designing monitoring programs, prioritising which provisions to monitor, survey intensity, monitoring duration, time of year and survey techniques.
- How to interpret site-based monitoring data and the relative effectiveness of mitigation measures for stakeholders (particularly consultants) to learn from individual project outcomes.
- How to accurately and efficiently report data to other stakeholders.

#### *7.4.3.3. Scope for improvements within SNCBs*

More detailed proposals for the design and rationale of site-based monitoring programs should be a compulsory component of licence applications. Describing programs more explicitly would provide transparency to roost owners and allow practitioners (including third party practitioners) to accurately tender for this work – either immediately following licence approval or at a later date.

Replacing the current system of using licence expiration dates with a more task-oriented completion system would also be a more logical way of concluding licensed mitigation projects. For example, licences could continue until evidence of all proposed measures and monitoring data has been submitted, or reasonable justification has been provided for their absence. Of course, there could be many legitimate reasons why such data may be absent, such as developments being cancelled, unforeseen health-and-safety / access issues preventing further survey work, or consultants proven to have made reasonable effort to contact roost owners.

Providing accountability to named individuals would increase the likelihood of monitoring actually being triggered and followed-through. This would primarily be the named licence holder, but could also include other individuals such as the named ecologist or site manager. Such accountability, including the requirement to submit monitoring data, should be made clear and explicit in the licence (not just method statements) to prevent this detail being overlooked. In addition, a semi-automated ‘prompting’ system for reminding individuals in advance of monitoring surveys may go some way to improving implementation rates. This could operate in a similar manner to the current system where licensed consultants are prompted to renew survey licences before they expire.

Such a system could be further expanded if named individuals were alerted if SNCBs had not received monitoring reports by a pre-agreed date. This kind of semi-passive enforcement could be implemented in a hierarchical way whereby the absence of such reports firstly prompts a friendly and polite e-mail, but replaced by increasingly more formal e-mails / letters if no responses have been received within a set time-frame.

#### *7.4.3.4. Monitoring report requirements*

Setting clear benchmarks for report content may help improve implementation by adding clarity at the outset and possibly preventing LPAs and SNCBs needing separate deliverables. For long-term programs, regular 'interim' reports would not only keep SNCBs updated, but also help the process retain momentum during long project timescales. This would also act as a safeguard against communication dead-ends where, for example, ecologists may leave projects or roost owners move properties before programs are concluded.

#### *7.4.3.5. Scope for improvements within consultancies*

Tendering for monitoring work, possibly years in advance, is inevitably problematic. However, if ecologists were encouraged to provide indicative fee proposals prior-to or following licence approval then this would provide clarity to roost owners regarding their financial commitments.

Although it has been argued that the basis for such arrangements should be written into method statements as safeguards, this study did not find any evidence that such actions were effective. It is also important that both clients and ecological practitioners are not locked into long-term contracts unless they can commit to them. The system should be sufficiently robust that consultants are free to withdraw from projects with confidence that monitoring will nonetheless continue without their direct involvement. Likewise, roost owners should retain the right to consider ecological support from elsewhere if they wish to do so.

It would also be prudent for ecological consultants to either introduce or review any systems currently in place for actively monitoring in-house development licences. Such a system would need to specify what interventions are necessary for ensuring adherence to monitoring requirements, how such interventions may be triggered and also where the data is stored and how it is used e.g. being sent to the local records centre and case studies shared online

### 7.4.4. Effectiveness of Monitoring Programs

#### *7.4.4.1. Summary of monitoring survey effort and duration*

Results indicated that night-time survey techniques were consistently more effective than daytime techniques at detecting bats that roosted in smaller external cavity-type roosts. In contrast, internal smaller-cavities and voids consistently relied on daytime techniques or a combination of both daytime and night-time techniques to detect bats. In general, it was found that the more survey effort carried out on sites and structures, the more bats and roosts were likely to be found. Sites with a disproportionately high volume of baseline data compared to post-development monitoring were therefore less likely to be considered successful compared to sites with good quality monitoring data but poor baseline data. However, analysis indicated that increasing the number of monitoring surveys beyond three may result in diminishing returns in terms of the number of newly identified bat roosts relative to survey effort.

In terms of bat monitoring duration and colonisation times, although roost occupancy rates increased over time our results also indicated that bats started occupying new provisions very soon after installation and that most of the effective provisions had become occupied within two years. Although there was a level of uncertainty in the reliability of the model, its evaluation did suggest that increasing the duration of monitoring programs beyond two years may result in diminishing returns for detecting bat occupancy rates in new provisions. However, it must be noted that this analysis was based upon data that was not species-specific and both day-roosts and maternity colonies were combined. Therefore, results may be more applicable to smaller day roosts of *Pipistrellus* spp which accounted for most active roosts in this project.

## 7.4.5. Barriers and opportunities for improving the effectiveness of monitoring programs

### *7.4.5.1. Purpose and rationale of monitoring programs*

Lintott and Mathews (2018) concluded that bat mitigation schemes currently lack a clear rationale for post-development monitoring. It is therefore important that any future proposals to reform the monitoring process carefully clarify how monitoring data will be applied and the processes it is intended to inform. Possible monitoring applications may include:

- Summarising the effectiveness of mitigation measures
- Providing closure, feedback and positive incentives to those involved in mitigation schemes.
- Provide a triggering point for taking adaptive management actions if mitigation is found to be ineffective.

If schemes are designed with clear outcomes that can be measured during the post-development monitoring stage, they could provide a clear approach to evaluating mitigation success at different scales. Assuming the ultimate goal of monitoring data is to assess the effectiveness of specific mitigation measures, data may be collected on various attributes such as specific roosting provisions, habitat or light-levels.

### *7.4.5.2. Use of EPS licence monitoring data as conservation evidence*

This study has demonstrated how data from standard monitoring programs completed by ecological consultancies may be used to further our understanding of different mitigation and compensation measures. Although conservation evidence is generally associated with published scientific research (Stone et al 2013, USAID 2018), ecological practitioners could potentially generate an extremely large volume of evidence through real-world efficacy / validation monitoring and documenting the outcome of mitigation programs. There is therefore an opportunity for both ecological practitioners and roost owners / developers to play an active role in building an actionable evidence base and potentially influencing the bat conservation processes that underpin the profession

Use of a standardised and quantified system for documenting compensation roost effectiveness has already been recommended in recent studies (Stone et al 2013; Mackintosh 2016; Lintott and Mathews 2018) and is similarly advocated here. Indeed, a recommendation for publishing mitigation successes and failures was made by Briggs (2004) fifteen years ago. Since such data is being collected anyway as part of routine monitoring practices (Mackintosh 2016), reforming how such information is reported, stored, analysed and evaluated by SNCBs could potentially be a powerful conservation tool for testing assumptions about different bat mitigation and compensation measures. Although the effectiveness of different provisions may not necessarily be directly related to the FCS of bat species, the ability to analyse such data from a large number of sites over a wide geographical area in a range of habitats and time-frame would more clearly indicate whether such measures should at least be advocated, refined or abandoned. This would provide a systematic framework for developing knowledge and increasing the effectiveness of future bat mitigation schemes, reducing the risk of perpetually using ineffective measures and increase opportunities for replicating success (USAID 2018).

Although there may be a perception that monitoring data may assess whether schemes have impacted a bat's FCS, it is questionable whether this is feasible at the site-level, even with an extremely comprehensive and long-term monitoring strategy. This is likely to be beyond the scope of most individual licencing schemes to demonstrate whether impacts have been positive or negative. Impacts at this scale are cumulative in nature and probably need to be evaluated at a landscape level using the information gained from numerous licence returns. However, if such a long-term and large-scale monitoring scheme was successfully established then this may provide scope for SNCBs to more thoroughly evaluate cumulative impacts and outcomes, allowing them to better determine that statutory obligations are being met (Lintott and Mathews 2018).

### *7.4.5.3. A Suggested Approach for Applying Monitoring Data*

- During BCT’s efforts to acquire case studies for this project, ecological consultants frequently cited a lack of time and problems associated with sourcing the necessary information as the primary reasons why they were unable to contribute to the project. Therefore, the most appropriate time for capturing this information is likely to be during the licensing process itself, as the SNCBs have the authority to require the relevant data to be submitted.

- Using recommendations made by Battersby (2010), it may be more efficient for practitioners to input quantified monitoring data directly into an online system themselves with SNCBs performing a data validation / verification exercise.
- Assuming the aim of data collection would be to test current assumptions about provision usage, rather than a more general aim of gathering data on bats, then survey effort during monitoring would also need to be structured more rigorously. Data would therefore need to be collected on the type of roost structure and basic access point, building and site attributes. Data on geographical and temporal variations may also prove extremely valuable.
- It must be acknowledged that quantifying an exhaustive set of all potentially valuable attributes, under the assumption that some of them may eventually reveal interesting findings, is unlikely to be workable or sustainable for a long-term monitoring program which would need to be streamlined. Therefore, it would not be advisable for such a database to wholly replace or effectively substitute for more detailed monitoring reports. However, if such reports contain the necessary information, are digitised and effectively stored then the data held within them could also be evaluated as part of more focused studies into specific questions about bat mitigation data. It is likely that some combination of both approaches would be the most effective and efficient compromise.
- Successfully establishing such a long-term and large-scale monitoring scheme is likely to involve developing a pilot study to test its ability for efficiently acquiring and effectively delivering the required level of information (Battersby 2010).

#### *7.4.5.4. Improved Standards for Monitoring Reports*

Although BCT's good practice guidelines (Collins 2016) and CIEEM's Guidelines for Ecological Report Writing (CIEEM, 2017) both emphasise that monitoring reports cover the mitigation measures undertaken and the degree to which they were implemented and effective (Collins 2016), they do not specifically cover monitoring report content which is more fully laid out in BS42020 clause 11.2.3.4 (BSI 2013).

Although it is clear that implementing such monitoring programs at a site-level is likely to be a significant barrier to widely adopting effective evidence-based techniques, it is important to put this into context. For monitoring to have an effective role in evidence-based practices, data collection is only a part of the wider processes. Such programs also need to be carefully planned, the monitoring data accurately submitted, appropriately stored, evaluated, reported and acted upon. Therefore, although monitoring data in BCT's sample was clearly lacking, data was nonetheless collected to some extent in 67% of cases. However, since there is currently little guidance on how such information should be reported to SNCBs, the monitoring process appears to deteriorate significantly after this stage. Even if monitoring data had been reported to SNCBs effectively, it was frequently not stored in a manner which allowed analysis, evaluation and learning.

## 7.5. Recommendations

- Post-construction monitoring should be carefully considered for all licence applications with a clear rationale and detailed methodology, including what actions will be triggered by different monitoring outcomes.
- More detailed post-construction monitoring guidelines should be produced to standardise practice and make the process more transparent, consistent and predictable for stakeholders. The guidance should include information on the rationale, design and reporting of monitoring.
- Licences should be extended until evidence of all proposed measures and monitoring data has been submitted, or reasonable justification has been provided for their absence.
- SNCBs should make clear what proportion of sites will be subject to compliance visits and what is the rationale for choosing those sites.
- Individuals (generally roost owners/licence holders) should be named on the licence as being accountable for the implementation of monitoring and a semi-automated system should be designed to prompt monitoring at the appropriate time and follow-up if monitoring reports are not submitted by a given deadline. This system would help to trigger monitoring surveys even in the absence of the original ecological consultant.

- Ecological consultants should tender for monitoring work up front to provide clarity to roost owners regarding their financial commitment to a project.
- Ecological consultancies, and in particular named ecological consultants, should have a system in place to ensure that monitoring commitments are fulfilled for all relevant licences.
- Metadata relating to the monitoring of licensed development work should be systematically collected/collated into a database as part of the licensing process to allow for future analysis of monitoring data. This could also facilitate an assessment of cumulative impacts of licensed development work.
- SNCBs should be provided with the resources to monitor compliance with licence conditions such as monitoring and carry out enforcement in cases of non-compliance because licence conditions are legally binding.
- Unless they can be fully inspected *in-situ* (for example, bat boxes), night-time monitoring should be used to detect bats roosting in small external cavity roosts.
- Day-time monitoring or a combination of day and night-time monitoring should be used to detect bats roosting in voids or small internal cavity roosts.
- More efficient ways to monitor mitigation should be developed, given the availability of new technologies such as remote sensors.
- Monitoring should be carried out within the first two years of installation but could be carried out up to five years after installation for higher-status roosts.

# 8.0. Roost Owner Attitudes

## 8.1. Background

Where possible, BCT always endeavoured to complete informal interviews with roost owners in person to gather information about their attitudes and opinions regarding key elements of the planning and EPS licensing process, their experience of working with ecologists and bats in general. Such interviews were predominantly intended for individuals involved in the original EPS licence work or those who had responded favourably to BCT's request for survey and were therefore living or working in the same location as the roosting provisions. Such interviews were not always feasible or considered appropriate for certain sites where BCT had not liaised directly with such individuals.

## 8.2. Methods

Roost owner interviews were completed at 44 sites. The following questions were asked:

1. Why did they respond positively to BCT's request to take part in the project?
2. How aware were they about whether bats used any of the roosting provisions?
3. What was their original attitude towards bats and bat conservation before the development process?
4. Did their attitude change during the development work? If so, how?
5. What were the most positive parts of the experience?
6. What were the most negative?
7. To what degree did they discuss bat conservation with their ecological consultant? If so, what aspects were discussed?

## 8.3. Results and Discussion

This project relied on a self-selection sampling strategy where roost owners willingly volunteered to participate. It is therefore likely that BCT's sample represents a disproportionately high number of roost owners with favourable attitudes towards bat conservation. Therefore, it is perhaps concerning that negative criticisms for both the planning and licensing process exceeded positive comments in those interviewed.

The most frequently reported positive comment about the EPS process was that bats and bat mitigation was interesting and educational (24%, n = 44). Other frequent comments included that contributing towards bat conservation was satisfying (20% of interviewees), their ecologist was helpful (20%) and the process as a whole was quite straightforward, well-defined and professional (12%).

It was noted in Year 1 that several roost owners actively praised the efforts of their appointed ecologist for their enthusiasm for bats. Several interviewees expressed that this positive experience had partially inspired them to participate in this project. In response, BCT asked an additional question to 21 roost owners in Year 2 as to whether their ecologist had spoken to them about wider bat conservation issues beyond the scope of their EPS licence. Most roost owners (62%, n = 21) either did not recall or reported that their ecologist focused on the site-specific mitigation measures, legal implications or the planning process. One roost owner reported that their household remained unclear why the surveys and mitigation were necessary or considered important. Nevertheless, 38% (n = 21) of interviewees in Year 2 reported lengthy discussions with their ecologist about bats, had been sent booklets, shown bats up-close and been encouraged to attend night-time surveys with them.

The collective work of ecological consultants may be highly influential in terms of the long-held conservation beliefs and attitudes held by members of the public. Compared to other stakeholders, ecologists are in a unique position where they often work very closely with individuals or companies over months or even years. It may therefore be easy to underestimate the importance of how the language and certain turns-of-phrases used in conversations, site meetings or reports to describe bats may influence beliefs and perceptions held by other stakeholders.

When asked to reflect on the most negative aspects of the EPS licence process, comments were generally more diverse. The most frequent responses related to the cost of baseline surveys (30%, n = 44) followed by associated delays when obtaining planning permission or informing EPS licences (23% of sites). Two interviewees recalled being surprised that it was domestic households rather than the government that were responsible for funding such work. A small proportion held negative attitudes towards the cost of licensed mitigation measures / supervision work (14%) and timing constraints during construction (11%). Negative feedback relating to excessive costs and timing delays, although frequent, were more typically related to the initial planning stages rather than the EPS licence process. However, both processes were frequently recalled together with roost owners typically not distinguishing between the two.

Interestingly, the formalised nature of the EPS process was both perceived as positive in some roost owners (11%) and negative in others (20%). Although certain interviewees responded favourably to its structured nature, others found the process quite stressful. One family were taken aback when presented with a letter stating their EPS application would be withdrawn and not re-considered if it was not presented in the correct format. Another household reported they had already received planning consent and started development before being made aware of a potential bat-related conflict by the police, subsequently being threatened with penalty fines and imprisonment despite having ceased work.

Other issues included a general inconsistency in approach and poor communication between LPAs, ecologists and SNCBs. Although a small number of roost owners clashed with their ecologist or building contractors, such events were rare in our sample. Several individuals also recalled being told by friends and family that they would not obtain planning consent if bats were recorded.

One issue identified early on in the interview process was that interviewees were generally unfamiliar with bats before applying for planning permission. Although often unable to interview licence holders for commercial sites in person, they were invariably more familiar with the planning and licensing process than domestic roost owners who were usually experiencing it for the first time. Although perhaps inevitable, a general trend in roost owner feedback was that their introduction to bats had been rather abrupt or negative. Although we recorded no evidence that this incited negative attitudes towards bats (87% of interviewees retained positive or neutral attitudes), it did not necessarily endear roost owners to bats either. Several interviewees reported that these initial conversations were largely based around being denied planning permission or how to avoid heavy fines and prison sentences. Such introductions are likely to produce long-lasting impressions that bats are predominantly a planning issue or 'ecological constraint' that needs to be resolved rather than that continued roosting in buildings by bats is essential for many species survival.

Another issue was a general sense of fatigue and cynicism towards the planning and licensing process itself. Some interviewees reported that ecologists, SNCBs and LPAs frequently disagreed over bat mitigation details or took unreasonable lengths of time to resolve seemingly straightforward issues. Such occurrences tended to evoke a sense of confusion in roost owners and several still questioned why they had needed EPS licences a decade later, particularly if such recommendations were contradicted by different practitioners or assessors.

BCT also received feedback that consultants or LPA ecologists were occasionally apologetic for certain aspects of the process or gave the impression they were more of a procedural 'tick box' exercise than a legitimate conservation endeavour. It is likely that such comments were genuine attempts by practitioners to demonstrate empathy or establish a rapport with roost owners at stressful points in the project. Although perhaps understandable and well-intentioned, such remarks not only undermine the process as a whole but also UK bat conservation in general. For example, one roost owner was told that *P.pipistrellus* were 'common' and only legally protected throughout Europe on the merit of other less widespread species. The roost owner was therefore genuinely surprised to learn their new maternity colony was likely to be of high conservation value in the local area.

Finally, several roost owners reported being unclear of the ultimate aim of the EPS process. The implication conveyed to interviewees was that their commitment to bat conservation would be over once the baseline surveys had been reported, the EPS licence obtained or bats had been safely captured and excluded. Their obligation to building new provisions and / or the monitoring surveys had not necessarily been effectively communicated.

Ultimately, the above issues are likely to causes developers and roost owners to lose confidence in the process, accentuate project fatigue and discourage commitments to the latter stages of mitigation and post-development monitoring work. Such issues are not straightforward to resolve and proposing simple recommendations would not only be somewhat disingenuous but also underplay their complexity. However, a starting point may be to use some of the more encouraging feedback in this study to deliver a more positive experience for roost owners. This may go some way to motivating individuals and companies to understand the need to commit to the more long-term bat mitigation measures beyond the initial soft-demolition phase.

Similarly, roost owners are usually introduced to bats and bat conservation as part of the planning process. Research has demonstrated that the use of positive or negative framings can strongly shape environmental perceptions. (Lopez-Baucells *et al* 2017). Endeavours such as the Partnership for Biodiversity in Planning project (www.biodiversityinplanning.org), led by the Bat Conservation Trust, therefore have the potential to influence how LPAs communicate bat-related issues to the wider public.

## 8.4. Recommendations

- During training and mentoring ecological consultants should be encouraged to talk about wider conservation issues relating to bats and engage roost owners using information and participation in surveys where possible. Training in framing nature conservation may be appropriate.
- Ecological consultants should be encouraged to communicate to clients during the whole of the planning and EPS licensing process from the early project planning stages through to completion of monitoring. This will help roost owners to understand the commitment they are making.
- Training and awareness raising with LPAs will help to increase consistency of approach between ecological consultants, the licensing body and the LPA. This was one of the aims of BCT's Partnership for Biodiversity in Planning Project, which is now concluded. Although a proportion of LPAs engaged with this project there is more work to be done.
- Training and awareness raising with the police will help to avoid situations where prosecutions and penalties are threatened in situations where work has already ceased and roost owners are willing to cooperate. This is one of the aims of BCT's Wildlife Crime Project, which is ongoing.
- Licensing authorities should consider the language used in communicating to roost owners about their licences.
- Awareness about bat conservation and the legal process for development should continue to be raised among the general public and built environment professionals to manage expectations. This is one of BCT's aims and is also the role of BCT's Built Environment Project, which is ongoing.

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# Appendix 1. Glossary of Terms and Abbreviations

*Terms*

Access points: Distinguished from roosts in this study and refers specifically to the opening apertures leading into roost structures. This project also distinguished between internal and external access points, and also between ‘direct’ access points leading directly into roost structures, and ‘indirect’ access points such as open doors or windows leading into interim voids or crevices before entering a more direct access point into the roost itself.

Baseline stage: Survey data collected pre-development.

BCT monitoring stage: Survey data collected as part of BCT’s post-development monitoring surveys. This generally took place several years after the consultant monitoring stage was completed.

Conservation status: Site assessments in this project used an adapted version of ‘Figure 4. Guidelines for proportionate mitigation’ on page 39 of English Nature’s Mitigation Guidelines (Mitchell-Jones 2004) which distinguished between ‘common’, ‘rarer’ and ‘rarest’ bat species. Although acknowledged to require regional interpretation (Mitchell-Jones 2004), for the purposes of this project 'common' species include *Pipistrellus pipistrellus*, *Pipistrellus pygmaeus* and *Plecotus auritus*. All other species (including *Myotis nattereri*) were classified as 'rarer' in this project.

Smaller cavities: Roost structures defined as being too small for access by bat workers. Therefore, for the purposes of this project, larger ‘cavity-style’ bat boxes or open soffit boxes were nevertheless classified under this broad term. Smaller cavities were also sub-categorised as being ‘internal’ if they were accessed from an internal void or crawling space.

Consultant monitoring stage: Survey data collected by ecological consultants during post-development monitoring surveys following developments. Although some survey work continued after BCT’s monitoring stage, this was generally completed beforehand.

Destroy / Remove: Roosts (or their host structures) either ‘physically’ removed or ‘functionally’ destroyed if modification work to the structure or surroundings ultimately compromised the continued ecological functionality to the point it was effectively lost.

Host structure: The building or tree hosting the roost or compensation provision.

Modify: Roosts (or their host structures) where the overall structure was retained but with some alterations to size, shape, materials, access points or environmental conditions.

Non-intended provisions: Roosts or access points used by bats on new buildings (or the new sections of modified buildings) which were identified during post-development monitoring work, but not designed or specified as a bat roosting provision.

Non-Target Species: Bat species recorded during post-development monitoring surveys that were not identified during baseline assessments or specifically targeted in mitigation designs.

Provisions: Roosts or access points specifically created (i.e. compensation), modified or enhanced with the aim of attracting roosting bats.

Retained: Roosts identified during baseline surveys where neither the structure nor access points were subjected to any modification work. However, the building or other host structure itself may have been modified or subjected to temporary disturbance.

Roost: As per the current wildlife legislation, roosts were taken to be any places used by bats for protection or shelter (Collins, 2016). However, to retain consistency in BCT's study, it was necessary to specify how such places were interpreted. Firstly, roosts were taken to be the physical structure and not the individual animals or colony using them. Secondly, roosts were species-specific and therefore classified separately when used by multiple bat species. Thirdly, all roosts were classified independently from each other. For example, two bat boxes on the same wall were classified as separate roosts. Roost structures were broadly categorised into voids and smaller cavities.

Roosts of multiple occupation: Instances where more than one bat species was recorded using the same roost structure, although not necessarily at the same time or for the same purpose.

Roost owners: This generally refers to the owners or managers of properties hosting active bat roosts or roosting provisions during the operational phase of developments. This may be different from the individuals who originally applied for, or held, EPS licenses.

Roost status: Roosts were broadly classified as being 'higher' or 'lower' status. Lower status roosts included night-roosts, day roosts, occasional and transitional roosts. Higher status was reserved for structures assessed as hosting maternity colonies or hibernating bats. These were taken from 'Figure 4. Guidelines for proportionate mitigation' on page 39 of English Nature's Mitigation Guidelines (Mitchell-Jones 2004).

Site: This refers to individual structures (buildings or trees) where roosts were predicted to be affected or used to host provisions in the mitigation strategy. Note that this may be different from the original redline boundary since these often comprised very large areas and multiple structures not subjected to development or mitigation.

Target Species: Bat species recorded during baseline assessments and specifically targeted by proposed roosting provisions.

Occupied bat roosts: As well as the presence of live bats, this term also includes roosts where evidence of bat use (i.e. droppings) was recorded but may not have been occupied by live bats at the time of survey.

Voids: Roost structures defined as being large enough for access by a bat worker such as lofts, cellars, open barns or other internal rooms.

*Acronyms*

BCT: Bat Conservation Trust

CIEEM: Chartered Institute of Ecology and Environmental Management

EFF: The Esmée Fairbairn Foundation

EPS: European Protected Species

NE: Natural England

NRW: Natural Resources Wales

PRFs: Potential Roosting Features.

SNCBs: Statutory Nature Conservation Bodies

# Appendix 2. Process of acquiring sites and sampling

To fulfil the aims of the project, BCT needed to obtain a sufficient number of case study sites that not only met the selection criteria, but also where EPS licence documents were readily available. Since there is no legal requirement for roost owners to provide access to third parties like BCT, it was not possible to use a completely random sampling strategy for the target population. Instead, the study used a self-selected sample by which roost owners willingly participated by inviting BCT staff to survey their property. However, since current data protection laws prevented BCT from contacting roost owners directly, case studies were obtained from two primary sources: 1) SNCBs; and 2) ecological consultants.

<u>SNCBs</u>

Regarding our Welsh case studies, NRW submitted 350 e-mails to roost owners on BCT's behalf in early 2017. This was followed by 714 letters in March 2018. Regarding the English case studies, Natural England submitted 1898 e-mails and 972 letters to roost owners in early 2017.

Only a proportion of roost owners responded positively to these requests. Response rates ranged from approximately 2.3% of roost owners responding to Natural England's letters / e-mails, to approximately 20% for those responding to letters posted by NRW.

NRW provided BCT with a 'Restricted Release Information Licence' for controlled access to certain information. This allowed us to directly access EPS method statements for the case studies received in Year 2. However, although Natural England also provided BCT with a 'Restricted Licence for reusing NE's Information and Data', it was not possible to obtain EPS reports for case studies where licences were issued before 2013. This was because such documents had not been digitised and the resources were not available to retrieve the paper documents from their off-site archives within the time available for this study. Since BCT was granted access to very few suitable sites where EPS licences had been granted after 2013 and development work was completed by the end of 2014, it was necessary to obtain EPS reports either directly from ecological consultancies or roost owners. A proportion of case studies therefore needed to be excluded from the study because: 1) we did not have access to the necessary EPS documents; or 2) the case studies did not meet BCT's selection criteria.

Ultimately, NRW's correspondence accounted for eight potential case studies in Year 1 and 145 in Year 2, while Natural England's correspondence accounted for 24 potential case studies in Year 1 only.

<u>Ecological consultants</u>

BCT initially shared resources with CIEEM as part of their own project examining bat mitigation (Lintott & Matthews 2018). CIEEM therefore distributed e-mails to their list of members in early 2017 which is understood to have been 4,986 individuals at the time (Lintott & Matthews 2018). CIEEM and BCT also used social media and personal contacts to directly target ecological practitioners. BCT continued to undertake these activities throughout 2017 and early 2018. This canvassing approach aimed to address ecological consultants directly. BCT requested that consultants first identify any potential case studies meeting our study criteria, then contact the respective roost owners for access on BCT's behalf, and finally submit EPS reports directly to BCT, but only if access was granted. It is understood that ecological consultants approached roost owners for at least 84 case studies during the project, of which 22 roost owners responded positively for sites that met the selection criteria.

<u>The sample</u>

The available information indicates that 4018 case study sites (i.e. 2870 in England, 1064 in Wales and 84 unknown locations) potentially met BCT's selection criteria and were contacted by the above methods. No sampling was used in Year 1 because of the restricted number of suitable case studies received. Therefore, every case study was surveyed where: 1) access and reports were available; and 2) sites met the selection criteria. In contrast, BCT received access to a surplus number of suitable case study sites prior to the 2018 field season in Year 2 (n = 145). This was due to the improved response rate from roost owners to NRW's letters in 2018. Since it was not possible for two BCT field staff to survey this volume of sites within the available time-frame, the following sampling approach was used:

- Sites where maternity colonies had been destroyed or modified during developments were preferentially selected over lower-impact schemes with fewer bats.
- From the remaining case studies with smaller bat roosts, sites featuring *Myotis* spp were preferentially selected. This was in response to the small number of sites in Year 1 featuring this species group.
- In the interest of equalising the representation of English and Welsh sites in BCT's sample, 24 Welsh sites were randomly selected for inclusion in Year 2 of fieldwork.

Overall, BCT collected data from a sample of 71 sites (42 English and 29 Welsh). Based on the information available, this was estimated to represent 1.8% of the total number of sites potentially available.

Countering bias

In the interest of examining potential sources of bias during within the study, BCT collected detailed information about each case study site and the manner in which it was made available. Since it was not feasible to perform a random sampling approach, four potential sources of bias were present in the sample:

- Roost owners - due to participants willingly putting forward their properties for inclusion in the study.
- BCT – since the final sample was inevitably influenced by logistical factors, weather conditions and the time required for field staff to survey sites.
- Ecological consultants - since they provided the necessary licence reports and contacted roost owners on BCT's behalf.
- SNCBs - since their own internal processes inevitably influenced report availability and the contact lists used for the mail-outs.

The first two sources of bias were a constant for all sites. The latter two were largely determined by the degree to which consultants and SNCBs contacted roost owners and provided reports. In the interest of minimising (but not eliminating) sample bias, consultants willing to provide case studies were requested to take certain measures for avoiding the preferential selection of certain case studies. This included either: 1) considering and putting forward all potential projects meeting the selection criteria; or 2) putting forward a random sub-sample of suitable sites. However, this generally did not happen because willing consultants were generally working from their own personal knowledge of familiar projects rather than a definitive list of every licensed bat scheme carried out by their company. Nevertheless, consultants were always encouraged to consider all sites meeting our selection criteria regardless of their perceived level of success or interest.

Desk and field processes

Case studies were analysed in detail to fully understand the project background. Full planning case history was obtained from Local Planning Authority (LPA) planning portals or directly from LPA offices to review relevant planning conditions, survey reports and planning drawings. EPS documents, method statements, mitigation drawings, application forms and post-development monitoring reports were also reviewed in detail. Baseline and post-development monitoring data was catalogued and quantified for later analysis and comparison to BCT's own monitoring data. Notwithstanding the original baseline roost data, any additional roosts reported by ecological consultants following soft-strip activities or capture / exclusion work were also included in the data set. Details of all retained, post-modified and new compensation roost provisions were catalogued on field 'tick-sheets' for efficient assessment during fieldwork.

## Appendix 3. Details of the most frequently used bat boxes recorded during the project

| Box Model | Photo (taken from NHBS website except for the last one) | Box attributes |
|---|---|---|
| Schwegler 1FF |  | AP width (mm): 22<br><br>Internal volume (cm$^3$): 1,672<br><br>Primary material: Woodcrete<br><br>Mounting class used in this study: Tree / wall (external & internal) |
| Schwegler 2F |  | AP width (mm): 18<br><br>Internal volume (cm$^3$): 3,300<br><br>Primary material: Woodcrete<br><br>Mounting class used in this study: Tree |
| Schwegler 1FR / 2FR |  | AP width (mm): 20<br><br>Internal volume (cm$^3$): 4,462<br><br>Primary material: Woodcrete<br><br>Mounting class used in this study: Wall (external); integrated) |

| Box Model | Photo (taken from NHBS website except for the last one) | Box attributes |
|---|---|---|
| Schwegler 2FN |  | AP width (mm): 20mm (front) / 35mm (base)<br><br>Internal volume ($cm^3$): 3,888<br><br>Primary material: Woodcrete<br><br>Mounting class used in this study: Tree |
| Schwegler 1FW |  | AP width (mm): 25<br><br>Internal volume ($cm^3$): 14,400<br><br>Primary material: Woodcrete<br><br>Mounting class used in this study: Tree / wall (external & internal) |
| Schwegler 1FD |  | AP width (mm): 12<br><br>Internal volume ($cm^3$): 3,888<br><br>Primary material: Woodcrete<br><br>Mounting class used in this study: Tree |
| Ibstock bat brick |  | AP width (mm): 22<br><br>Internal volume ($cm^3$): 1,620<br><br>Primary material: Clay<br><br>Mounting class used in this study: Integrated |

| Box Model | Photo (taken from NHBS website except for the last one) | Box attributes |
|---|---|---|
| Schwegler 1FQ |  | AP width (mm): 43<br>Internal volume ($cm^3$): 5,750<br>Primary material: Woodcrete<br>Mounting class used in this study: Wall (external) |
| Kent Bat Box |  | AP width (mm): 15<br>Internal volume ($cm^3$): 990<br>Primary material: Timber<br>Mounting class used in this study: Wall (external) |
| Habibat |  | AP width (mm): 30<br>Internal volume ($cm^3$): 1,890<br>Primary material: Brick<br>Mounting class used in this study: Integrated |
| American style (bespoke) |  | AP width (mm): 15<br>Internal volume ($cm^3$): 7,315<br>Primary material: Timber |

| Box Model | Photo (taken from NHBS website except for the last one) | Box attributes |
|---|---|---|
| | | Mounting class used in this study: Wall (external) |