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ORIGINAL ARTICLE

Influence of bat house design on hibernating bats - a case study in Herefordshire (UK)

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ABSTRACT

In England, bats and their roosts are protected by national legislation. To permit development actions that would otherwise result in an offence relating to bats, it is first necessary to obtain a protected species mitigation licence containing protective measures. Due to the complexity of the topic, combined with the fact that monitoring is often limited, it can be difficult for practitioners to be certain of real conservation benefits of these measures. To build a new access road near Hereford (UK), a former artillery magazine (confirmed bat roost) building was demolished. Therefore, a legally binding English Nature/Natural England European Protected Species (EPS) Development Licence was obtained (2005). This licence stipulated mitigation and compensation measures to ensure the works could be carried out without harming bats and ensuring their favourable conservation status was maintained. Roost compensation measures were applied to two identical retained buildings. These included blocking doorways, provision of bat access grilles/internal roosting crevices, diverting downpipes inside, and installing straw matting (approx. 5cm deep, within one building only). The latter two measures were designed to increase internal humidity levels. Pre-compensation monitoring recorded two hibernating common pipistrelles in addition to lesser horseshoe and brown long-eared bat droppings. Post-compensation monitoring (2006-2016) recorded a minimum of three brown long-eared bats, three lesser horseshoe bats, one common pipistrelle and one barbastelle, suggesting the compensation methods may have increased both the numbers of species, and individual bats. These increases were small, hence not conclusive. Notably, during the post-compensation hibernation monitoring, brown long-eared bats were found in areas with lower humidity levels (48.6-78.8%) than lesser horseshoe bats (67.8-93.5%). The magazine containing straw matting had winter humidity levels approximately 20% higher than the other and supported a higher number of hibernating lesser horseshoe bats, but a lower number of hibernating brown long-eared bats. Within both buildings, all hibernating brown long-eared bats were found behind chipboard (approx. 70cm x 150cm) attached to wooden battens approx. 2cm from the internal walls rather than wooden or sawdust/cement composite bat boxes.

INTRODUCTION

Bats use different roost types throughout the year, with nine types listed by Collins (2016). Some of these roost types (e.g. maternity and hibernation) will generally have a greater influence on the conservation status of a bat population than others (e.g. non-breeding day roosts). At the time of the work described, bats and their roosts in England were protected by both national (Wildlife and Countryside Act 1981, as amended) and European (The Conservation of Habitats and Species Regulations 1994) legislation. In order to permit actions that would otherwise result in an offence relating to bats, it was necessary for development projects to obtain a European Protected Species (EPS) Development Licence via the relevant Statutory Nature Conservation Organisation (SNCO), in this case English Nature/Natural England (EN/NE). Following Brexit in 2020, these are now referred to as 'protected species mitigation licences', issued under national 'Conservation of Habitats and Species Regulations 2017 (as amended)' legislation. The method statement associated with both forms of this licence is a legally binding document, containing measures to ensure populations of the species concerned are maintained at a favourable conservation status. This implies that both species populations and the habitats they require are viable in the long-term. In order to determine the best ways to do this for bats, examples of effective methodologies are shared via a number of books (Mitchell-Jones 2004, Mitchell-Jones & McLeish 2004, Mitchell-Jones et al. 2007, Schofield 2008, Howard & Richardson 2009, Gunnell et al. 2013, Berthinussen et. al. 2021), an online Bat Conservation Trust database (Bat Conservation Trust 2020), and scientific publications (e.g. Garland et al. 2017). Despite all available information, the large complexity of the topic, combined with the fact that monitoring is often limited and/or not scientifically rigorous, can make it difficult for practitioners to be certain of real conservation benefits.

The Conservation Evidence bat conservation synopsis (Berthinussen et al. 2021) only reports two studies (Mitchell-Jones et al. 2007, Zeale et al. 2016) which evaluated the effects of conserving roosting sites for bats in old structures or buildings, and no studies investigating the provision of artificial subterranean bat roosts to replace bat roosts in reclaimed mines. It is therefore important to share information when best practice methodologies relating to these topics are successful. In this case-study, such information resulted from the building of a new access road on the south side of Hereford (UK), linking the existing A49 and B4399 roads. This was required to relieve road congestion, improve access to the Rotherwas Industrial Estate, and reduce traffic volumes through residential areas. The alignment of this road was constrained by an existing Industrial Estate, and by an area of higher ground. Since these works required the removal of a known bat roost, a legally binding EN/NE EPS Development Licence (a requirement of The Conservation of Habitats and Species Regulations 1994 (relevant at that time)) was obtained. This licence stipulated mitigation and compensation measures to ensure the works could be carried out without harming bats and ensuring their favourable conservation status was maintained. Hereby, we present and discuss the success, as well as the advantages and disadvantages of these measures, as a case-study project from in the UK.

MATERIALS AND METHODS

The Industrial Estate and associated artillery magazines

The Industrial Estate is situated on the site of a wartime munitions factory, and a number of buildings associated with this past use remained present. These include a row of seven former artillery magazine buildings (Fig. 1), all of which were built to the same design (Fig. 2). Each magazine is single-storey and rectangular in shape (roughly 27m long x 8m wide), with external and internal brick walls (externally pebble-dash rendered). Internal dividing walls split the interior into 15 separate small rooms (Fig. 2). Each building has two external open doorways facing west, but no windows. There is a concrete floor, and flat concrete roof approximately 3m above floor level. Above the concrete roof, there is a separate void created by a pitched corrugated asbestos roof with brick end walls, which is in a poor state of repair on both Magazines 1 and 2. Health and safety concerns prevented surveying for the presence of bats in these upper voids in either building. Both magazine buildings were partially covered by ivy (*Hedera helix*).

Prior to access road construction, Magazine Buildings 3, 4, 5 and 6 were being used to store fireworks, while Magazines 1, 2 and 7 were disused. All were situated within cattle and sheep grazed fields, with an artificial earth mound (supporting patchy scrub) surrounding each building. There was a gappy mature hedgerow, running east-west, to the south of the magazines, which widened close to the easternmost magazine (Magazine 7) to incorporate several ponds. This hedgerow formed a link with woodland to the east, and linked to Magazines 1, 2, and 7, via landscape planting and semi-mature trees respectively. The wider agricultural landscape consisted of both pastoral and arable land, was well wooded, and the River Wye was approximately 1 km away. The site was adjacent to the aforementioned industrial estate to the north, which in turn had a western boundary directly adjacent to the City of Hereford.

New road construction and demolitions

It was unavoidable that the easternmost of the magazine buildings (Magazine 7) would be demolished as part of the new road construction, since this building was entirely within the land permanently required for the new road (i.e. the scheme corridor, see Fig. 1). Magazine 7 was a known bat roost, supporting hibernation and non-breeding day/transitional roosts for four species (although low in numbers). This study comprised enhancing two remaining buildings (Magazines 1 and 2) for roosting and hibernating bats, both of which were also used by bats, with the aim of compensating for the loss of Magazine 7 and enhancing the quality of bat roosting conditions available. After the road was constructed, Magazines 3, 4, 5 and 6 (none of which were identified during the initial surveys as roosts) were subsequently demolished to allow expansion of the adjacent industrial estate. This separate action is not detailed within this study. This means that Magazines 1 and 2 are now the only ones remaining.

Initial bat surveys (2001-2005)

A series of initial internal bat surveys (2001-2005) were undertaken by EN/NE licensed surveyors in all seven magazine buildings. These were undertaken by three companies (The Robert Stebbings Consultancy 2002, Halcrow, Cresswell Associates 2008), and aimed to determine the number and species of any bat species present, and to assess the purpose of their building use (as described by Collins (2016)). The exact methodology used by the first two companies is unknown but would have been similar to Cresswell Associates. This company used two surveyors (at least one of whom held an EN/NE bat survey licence), equipped with torches and a fibrescope, to survey the ground floors only. No bat activity, emergence or re-entry surveys were carried out, and droppings were identified from physical appearance only. These surveys informed the subsequent bat mitigation, compensation and enhancement strategies. Magazine 7 was demolished in 2005, under licence and Ecological Clerk of Works supervision to ensure no bats were harmed during the demolition. No bats were present at the time demolition took place.

Mitigation tasks and magazine enhancing (2005)

The retained Magazines 1 and 2 (Fig. 1) were enhanced in May 2005 immediately prior to the demolition of Magazine 7, aiming to compensate for the loss of the Magazine

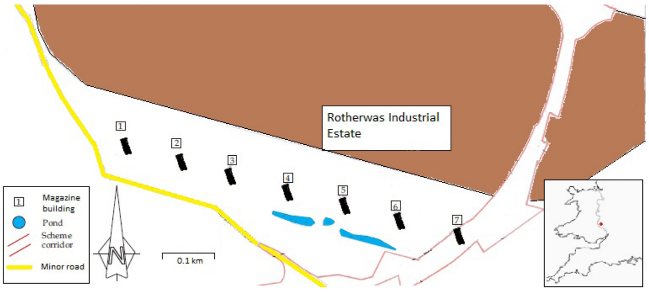

Fig. 1 – Magazine building landscape positions

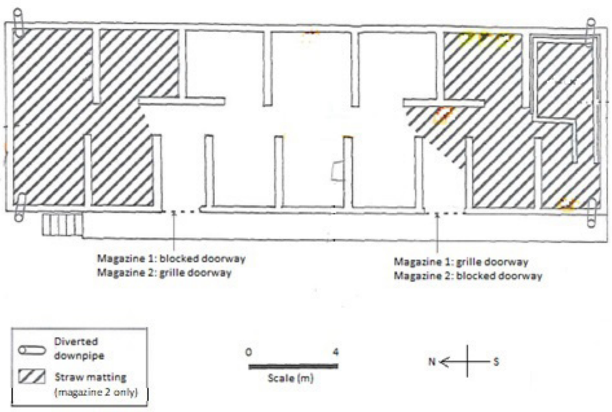

Fig. 2 – Magazine plan view

7 bat roost by improving their suitability, and achieving enhancements for net gain. As well as providing long-term bat roost provision, retention of Magazines 1 and 2 was also required for landscape reasons, as development of this area would affect views from adjacent housing. They were also considered to be of some local historic interest. The two magazine buildings have identical construction/aspects (Figs. 2 & 3a), similar surrounding vegetation (with nearby ponds: Fig. 1), are approximately 0.1km apart, and are within an area of grassland and scrub, bordered by hedgerows, all of which are owned and managed by Herefordshire Council. Magazine 2 was closer to the demolished Magazine 7, an approximate distance of 0.57km. In addition to a replication of conditions, proximity to the original roost is also important for the success of roost compensation measures. Such measures were required under the EN/NE EPS Development Licence. The measures undertaken at the two magazine buildings included:

- Blocking of one doorway with breeze blocks (Fig. 3a), incorporating one air brick no more than 1m above floor level to provide limited air-flow through the building. The north doorway of Magazine 1 and the south doorway of Magazine 2 were blocked in this way. This was done to improve bat roost conditions by limiting access for humans, light, and air flow.

- Provision of a grille of suitable dimensions for lesser horseshoe bats (*Rhinolophus hipposideros*), incorporating a locked gate for human access (for monitoring purposes), on the other doorway (Fig. 3b). The grille is the same design on both magazine buildings, and measures 88 cm wide x 63 cm high. There are three metal bars running across the grille, separating it into four gaps each 88cm wide x 15cm high. The grille is 1.4m from the ground, and is present as this species needs to be able to fly directly into and out of their roost (Schofield 2008). Internal baffles can be used behind such entrances to reduce ingress of light, wind, rain and predators (Schofield 2008). However, due to the large and complex nature of the internal spaces available to the bats in this instance, it was decided that internal baffles were not required.

- Repair of guttering, and re-direction of rainwater from downpipes into the inside of the building (to increase humidity within roost). This necessitated creation of several small holes in walls of the building, which were re-pointed around pipes to avoid changing air-flow patterns within the roost (Fig. 3c & 3d).

- Provision of used horse straw bedding (to a depth of approximately 5cm) on the floor of Magazine 2 only, to soak up water and ensure that high humidity levels were maintained between rainfall events (Fig. 3e). There was no commitment to regularly replace this (further discussed in conclusions).

- Internal bat roosting provision (Fig. 3f – 3i). This included rough untreated, timber planks on some ceilings within the magazines, and sections of chipboard (approx. 70cm x 150cm) attached to battens (approx. 2cm x 2cm) on walls (three per magazine), to provide perching sites for lesser horseshoe bats and crevices for other bat species. Additionally, four 1FF Schwegler bat boxes, and four wooden bat boxes were also installed for crevice dwelling species (brown long-eared (*Plecotus auritus*), common pipistrelle (*Pipistrellus pipistrellus*) and Natterer's (*Myotis nattereri*)) within each building. All of these species had been recorded on site.

Post-enhancement internal bat monitoring (2006-2016)

A series of post-enhancement internal bat monitoring visits (2006-2016) were then undertaken by EN/NE licensed bat surveyors in these two magazine buildings, in accordance with EPS Development Licence conditions. These were undertaken by Cresswell Associates/Hyder/Arcadis staff, using the same basic methodology used initially. Additionally, the majority of these monitoring visits also collected internal temperature and humidity data. This was done using tinytag loggers (Gemini Data Loggers, Chichester, UK) when recording internally overnight, and kestrel recorders (Nielsen-Kellerman Company, Boothwyn, USA) when collecting single recordings from specific internal points. Additionally, Anabat ultrasound detectors (SD1 and SD2 models) (Titley Scientific, Brendale, Australia) were also used occasionally to record overnight bat flight activity immediately outside of the magazine buildings. This monitoring aimed to collect information on bat use to both quantify whether the roost enhancements worked. No post-enhancement bat emergence/re-entry/activity surveys were carried out since the ground floor interior containing all the enhancements could be exhaustively investigated by surveyors. Additionally, such surveys would have provided little/no additional information during winter, when the majority of internal inspections were carried out.

Fig. 3 – Magazine bat enhancement photographs. These comprise: a) general view showing blocked door, b) grille and door, c) external pipework diverted internally, d) internal pipework, e) wet floor (and barn owl pellets) underneath Magazine 2 grille, f) rough untreated timber on ceiling, g) internal Schwegler 1FF bat box, h) internal wooden bat box, and i) internal rough wooden boarding (beneath historic light fitting panel).

RESULTS

Between 2001 and 2005, four species of bats were recorded using Magazine 7 (Table 1). These comprised peak counts of one lesser horseshoe bat, one brown long-eared bat, two Natterer's bats, and one common pipistrelle. During the same period, no bats were directly observed roosting within Magazine 1, although there were small numbers of lesser horseshoe and brown long-eared bat droppings found, consistent with use of the structure as a feeding and/or night roost. A similar pattern was recorded for Magazine 2, with the addition of two hibernating common pipistrelles found during the winter of 2003/04. Four surveys between 2001 – 2005 found no evidence of bats within Magazines 3, 4, 5 and 6. Approximately five years after Magazines 1 and 2 had been enhanced, only minor increases in bat use were recorded during internal monitoring (2006-2010: Tables 1 & 2 Supplementary Material). However, the number and species of bats present within both magazine buildings increased further during the later post-enhancement monitoring (2012-2016: Fig. 4; Tables 1 & 2 Supplementary Material).

During the entire post-enhancement monitoring period (2006-2016), the winter visits (i.e. during October to March inclusive) recorded higher numbers of brown long-eared than lesser horseshoe bats in Magazine 1, when calculated as maximum winter counts (Fig. 4). Between 2012 – 2016 the winter internal humidity levels ranged between 48.6 – 78.8% in Magazine 1, and between 71.3 – 93.5% in Magazine 2. In contrast, the winter temperature recordings were closer, ranging between 8.2 – 13.5ºC in Magazine 1, and 7.0 – 13 ºC in Magazine 2 (Fig. 5; Tables 1 & 2 Supplementary Material).

The situation was different for summer (April – September) surveys, with Magazine 1 being used more frequently by both lesser horseshoe and brown long-eared bats (Fig. 4; Tables 1 & 2 Supplementary Material) albeit in low numbers. Between 2012 – 2016 the summer internal humidity levels ranged between 52 – 94.2% in Magazine 1, and between 67.8 – 100% in Magazine 2. Similar to the humidity readings, the summer temperature recordings were closer and ranged between 4.4 – 26.5ºC in Magazine 1, and 4.2 – 21.5 ºC in Magazine 2 (Fig. 6; Tables 1 & 2 Supplementary Material).

The design and dimensions of the roost access grille were not sufficient to prevent bird access. Barn owl (*Tyto alba*) pellets were discovered just inside the entrance to Magazine 2 on 8th April 2013 (Fig. 3e), and a small number of both active and recently active swallow (*Hirundo rustica*) nests were found inside both magazine buildings on multiple occasions.

Table 1 – Initial day time internal inspection bat surveys (ground floor only). *Roost type classified according to Collins (2016).

Magazine building	Survey timing	Surveying company	No. of surveyors	Equipment used	Bat evidence	Roost type*
1	2001 (3 surveys)	The Robert Stebbings Consultancy Ltd	Unknown	Unknown	Small number (approx. 20) of lesser horseshoe bat droppings.	Possible night
	2002 (January and June)	Halcrow	Unknown	Unknown	No evidence of use by bats	No evidence
	July 2003 Feb 2004 (3+ surveys)	Halcrow	Unknown	Unknown	Small numbers of lesser horseshoe and brown long-eared bat droppings, and some feeding remains (moth wings) (late autumn 2003).	Feeding (for one or two species),
	Spring 2004	Cresswell Associates	2	Fibrescope, torch	No evidence of use by bats	No evidence
2	2001 (3 surveys)	The Robert Stebbings Consultancy Ltd	Unknown	Unknown	No evidence of use by bats	No evidence
	2002 (January and June)	Halcrow	Unknown	Unknown	No evidence of use by bats	No evidence
	July 2003 – Feb 2004 (3+ surveys)	Halcrow	Unknown	Unknown	Small numbers of lesser horseshoe and brown long-eared bat droppings (late autumn 2003). Two hibernating common pipistrelles (Feb 2004).	Hibernation, plus possible feeding/ night.
	Spring 2004	Cresswell Associates	2	Fibrescope, torch	No evidence of use by bats.	No evidence
3 - 6	2001 (3 surveys)	The Robert Stebbings Consultancy Ltd	Unknown	Unknown	No evidence of use by bats	No evidence
	Unknown (1 survey sometime between 2002 - 2004	Halcrow	Unknown	Unknown	No evidence of use by bats	No evidence
7	2001 (3 surveys)	The Robert Stebbings Consultancy Ltd	Unknown	Unknown	One lesser horseshoe bat, one brown long-eared bat, and two Natterer's bats.	Lesser horseshoe bat recorded on each survey: building used during winter and summer by multiple bats simultaneously (hibernation and transitional/day roosts)
	2002 (January and June)	Halcrow	Unknown	Unknown	No evidence of use by bats	No evidence
	July 2003 – Feb 2004 (3+ surveys)	Halcrow	Unknown	Unknown	No evidence of use by bats	No evidence
	Spring 2004	Cresswell Associates	2	Fibrescope, torch	One lesser horseshoe bat	Transitional/day
	April 2005	Cresswell Associates	2	Fibrescope, torch	One lesser horseshoe bat and one common pipistrelle bat.	Transitional/day

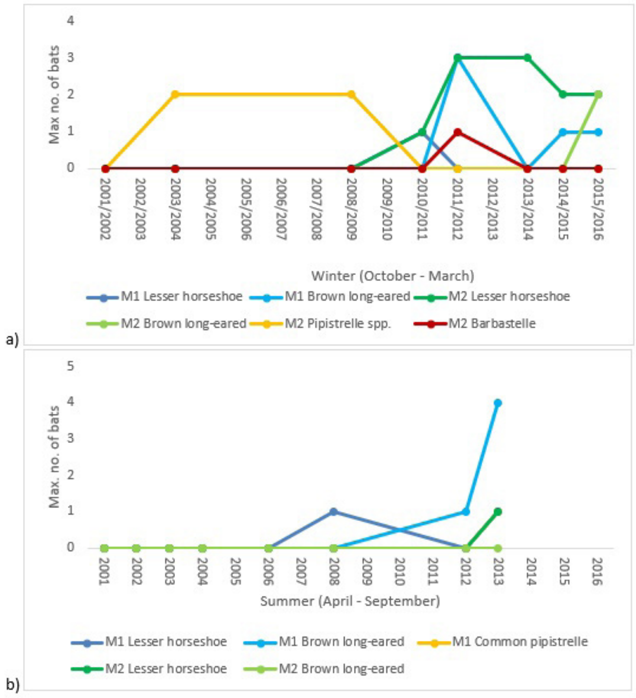

Fig. 4 – Maximum number of each bat species recorded per season within Magazines 1 (M1) and 2 (M2) during (a) winter (October-March) and (b) summer (April-September). 4b) One M1 common pipistrelle and one M1 lesser horseshoe also recorded in 2013 (hidden by M2 lesser horseshoe Magazine enhancements carried out in May 2005.

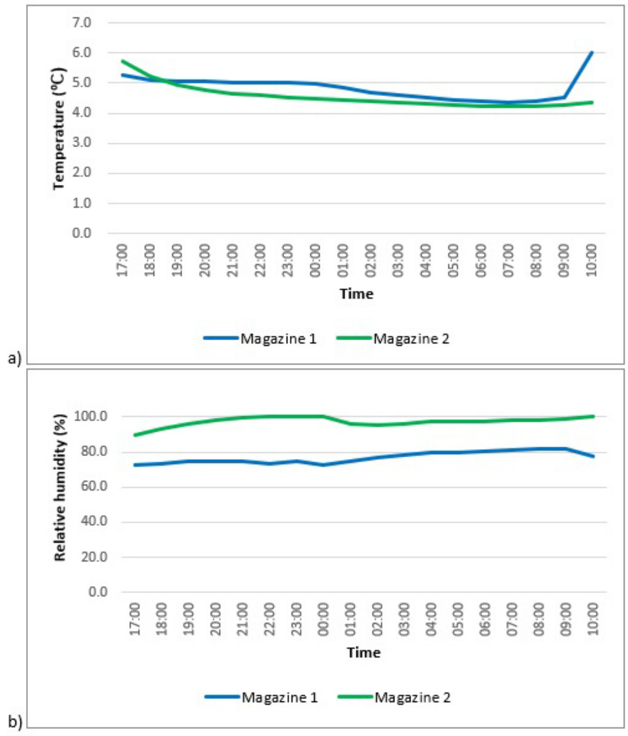

Fig. 6 – Internal magazine hourly tinytag (a) temperature (ºC) and (b) relative humidity (%) readings 08 - 09/04/2013.

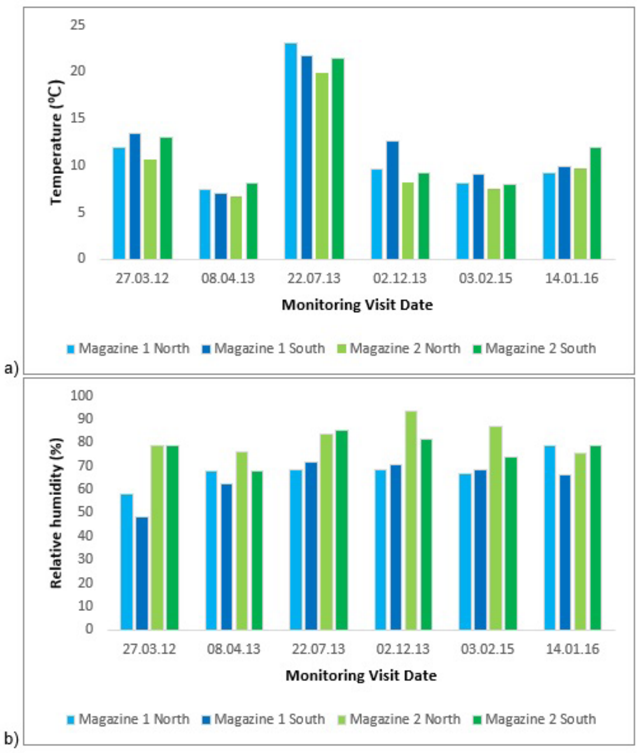

Fig. 5 – Internal magazine (a) temperature (ºC) and (b) relative humidity (%) readings.

DISCUSSION

Although bat use of Magazines 1 and 2 did increase over the post-enhancement monitoring period, the increase was small. As such, it is not conclusive whether the observed increases were associated with enhanced internal conditions or were as a result of changes happening elsewhere (e.g. Magazine 7 and/or another roost no longer being available to the bats, or increases in bat populations necessitating use of additional hibernation roosts). The magazines' internal temperatures were too low for optimum maternity colony conditions, so their continuing use by only non-breeding bats in summer is not surprising. The average daily temperature of brown long-eared bat nursery roosts in Scotland ranged from 10.5°C to 26.6°C, with individuals using torpor to conserve energy at a wide range of roost temperatures below about 22°C (Entwistle 1994). The mean temperature of a roof apex where a maternity colony of lesser horseshoe bats clustered was 30.9°C (Schofield 2008).

In contrast to maternity colony conditions, Magazine buildings 1 and 2 provided better conditions for hibernating and non-breeding bats. This replicated the use bats made of the demolished Magazine 7 (Table 1). Harmata (1969) recorded captive brown long-eared bats choosing to hibernate at temperatures between 1-8°C, with most individuals selecting 6°C. A review of natural hibernation site studies (Webb et al. 1996) described a larger range (0 - 9°C). The same review described a range of 5 - 12°C for common pipistrelle, -3 – 6.5°C for barbastelle, and 2-13°C for lesser horseshoe. In the UK, temperatures recorded near hibernating lesser horseshoe bats range between 5 - 11°C; at the higher end of this range until late December when a high proportion leave to feed on mild nights; lower in January to March when feeding is usually less frequent (Ransome 1991 pers.comm). Continuous temperature recordings obtained by Roger Ransome from multiple underground sites during multiple winters at Combe Down (UK) show that lesser horseshoe bats occur at similar thermal conditions to greater horseshoe bats (*R. ferrumequinum*) (described by Ransome 1971). Lesser horseshoe bats show the same dusk foraging synchronisation as greater horseshoe bats in October and April/May, suggesting that they need dampened, but fluctuating temperature ranges (i.e. no stability at any stage) throughout winter hibernation (Ransome, pers. comm.). This would allow the most advantageous arousal frequency for foraging (Ransome 1971).

In the Netherlands, Daan & Wichers (1968) found the relative humidity of limestone caves around hibernating long-eared bats (either *P. auritus* or *P. austriacus*) to be 95-100%. Recommended purpose-built lesser horseshoe bat hibernacula conditions include nearly 100% humidity (Schofield 2008), and a variety of temperature conditions between 6-10.5°C (based on Ransome 1971). Inward downpipes were installed to create humid conditions in both retained Magazines 1 and 2. Straw matting was only installed in Magazine 2, in order to maintain high humidity levels in this building and hence provide bats with a choice of conditions. As the buildings were otherwise identical and with similar internal temperature regimes, results suggest that the higher humidity levels recorded in Magazine 2 were actively selected by lesser horseshoe in preference to the lower humidity levels in Magazine 1 (as would be predicted from advice provided by Mitchell-Jones (2004), and Schofield (2008)) but that, in contrast to Daan & Wichers (1968), brown long-eared bats actively selected the less humid conditions for hibernation. The only time this species was recorded hibernating in Magazine 2 was on the last monitoring visit (2016) when the humidity levels were lower (Table 2 Supplementary Material). Lower hibernation humidity levels may therefore be preferred, despite this not currently being supported by other literature (Daan & Wichers 1968, Bogdanowicz & Urbanczyk 1983, Lesiński 1986).

In situations where straw matting and diverted rainwater are appropriate for the structure, a deeper layer of earth/ straw matting might increase the humidity levels further and remain effective for longer, since it is likely the influence of the straw matting decreased over time. Alternatively, a shallower layer of straw matting (5cm deep, as used in this study) could be replenished at regular intervals no longer than 10 years. During the last monitoring visit (2016 – 10.5 years after creation), a higher humidity level was recorded in Magazine 1 than Magazine 2 (Tables 1 & 2 Supplementary Material).

All the roosting brown long-eared bats, within both magazine buildings, were found behind wooden panels. Although brown long-eared bats often roost within voids (e.g. attics (Gaisler 1966)), they can also roost within crevices (Simon et al. 2004). As Entwistle (1994) found this species using the darkest available area to roost in, higher ambient light levels may encourage crevice roosting. However, as the Magazine building interiors were very dark (the only light being from the entrance grilles), the reasons for their use in this case are unclear. A similar scenario associated with a Wiltshire (UK) railway tunnel case study, where wood was attached to internal walls, is described by Mitchell-Jones et al. (2007).

Barn owls could have impacted on bat use of the magazine buildings, particularly within Magazine 2 where the pellets were found. Barn owl pellets were only found on one occasion (8th April 2013), and this did correspond with no bats being found within Magazine 2 (Table 2 Supplementary Material). Barn owls do predate bats, usually opportunistically although they can sometimes specialise on them (Roulin & Christe 2013). The smallest recommended barn owl access dimensions (100 x 100mm, Barn Owl Trust (2012)) are smaller than the smallest recommended lesser horseshoe bat access dimensions (300 x 200mm, Mitchell-Jones & McLeish (2004)). However, a smaller roost access combined with a baffle (Schofield 2008) may discourage barn owl access. Given their roosting and emergence behaviours, lesser horseshoe bats would be expected to be at greater risk of predation than brown long-eared bats (i.e. by roosting in the open and light sampling extensively at roost entrances). However, Magazine 2 continued to be selected in preference to Magazine 1 by lesser horseshoes in every winter monitoring period since evidence of barn owl presence was found.

This study did have limitations, notably the absence of emergence/re-entry surveys prevented an assessment of other potential roosting areas (such as cavities within the roof and walls) which could not be visually inspected. Internal temperature and humidity readings from every survey and monitoring visit, and more frequent monitoring (at least one summer visit each year) would have enabled better assessment of the differing humidity regimes on summer roosting bats. Additionally, there was a relatively low number of bats observed using both magazine buildings, albeit with the caveat that not all areas could be inspected. Although enough data was obtained to allow a comparison between internal conditions, the magazines are unlikely to influence overall bat population conservation status (i.e. only local significance) and therefore may not have provided optimum hibernacula conditions.

CONCLUSIONS

1) In comparison with Magazine 1, hibernating lesser horseshoe bats preferred the higher humidity levels associated with Magazine 2. The use of measures to increase and maintain high humidity, such as straw matting and inward facing drainpipes where this will not compromise the integrity of the structure, is therefore recommended when creating hibernacula for this species.

2) In comparison with Magazine 2, hibernating brown long-eared bats preferred the lower humidity levels associated with Magazine 1. A range of humidity levels is therefore recommended when creating bat hibernacula.

3) All the roosting brown long-eared bats, within both magazine buildings, were found behind wooden panels. None were found roosting in the magazines during the initial surveys prior to panel installation, hence the presence of these panels may be important for this species. The panels were chipboard, although since panels of no other material were provided for comparison, the extent to which this species prefers this material remains unknown.

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