English Heritage Research Project: 6199

Management of Bats in Churches – a pilot

Project Report
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University of Bristol

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Executive Summary: Management of Bats in Churches - a pilot

A significant proportion of medieval churches are home to bats, with a minority of these hosting large and important maternity roosts. Where large numbers of bats are present, this can impact upon the church, disrupting use for worship and community events, causing damage to objects and materials of heritage and religious value, increasing the cleaning burden and giving rise to perceived health risks. Balancing the needs of these protected species with the preservation and use of churches is challenging. A Defra-funded research project (WM0322) 'Improving mitigation success where bats occupy houses and historic buildings, particularly churches' led by the University of Bristol and completed in 2014 has advanced understanding in this area. This pilot project applies and builds upon the results of project WM0322, researching and developing management techniques to enable churches severely affected by bats to implement cost effective measures to protect heritage (some of national and international significance) in ways which will cause no long-term detrimental impact on the local bat population (or the Favourable Conservation Status[1] of the bats).

In addition, this pilot study addresses knowledge gaps remaining from project WM0322, in which the impacts of deterrents on Natterer's bats (*Myotis nattereri*) were investigated in churches in late summer but not in spring/early summer when bats are pregnant and sensitive to disturbance. Furthermore, the effectiveness of deterrent techniques on another species which can form large roosts in churches, the soprano pipistrelle (*Pipistrellus pygmaeus*), needed to be investigated.

The study was conducted May-September 2014 in five churches with problematic maternity roosts: four churches in Norfolk with Natterer's bats and a church in Northamptonshire with a large soprano pipistrelle colony. Bats were radio-tagged and their behaviour and roost locations monitored in relation to deterrent and bespoke measures, along with daily mapping of roost sites, dropping deposition and regular roost counts.

Key research findings:

1. Acoustic deterrents were an effective tool in reducing the impact of Natterer's bats on churches.
2. Natterer's bat and soprano pipistrelle roost locations could be manipulated with acoustic deterrents in spring/early summer.
3. Soprano pipistrelles eventually habituated to acoustic deterrents.
4. Light deterrents adversely affected bat behaviour and trapped bats within their roosts.
5. 'Boxing-in' roosting areas around bats' entry points into a church was found to provide a promising solution, retaining roosting space for the bats but preventing access (and therefore deposition of droppings and urine) to the rest of the church interior.
6. The operation of techniques and equipment were refined to create a toolkit for the effective and safe management of bats in a church context (based on findings for Natterer's bats and soprano pipistrelles), including a guidance document on the use of deterrents and bespoke 'boxing-in' measures.

[1] The concept of 'Favourable Conservation Status' is central to the EC Habitats Directive and the conservation status of a species can be defined as the sum of the influences acting on the species concerned that may affect the long-term distribution and abundance of its populations.

Introduction

Scope of the Report

To outline findings from the project 'Management of Bats in Churches – a pilot', under contract from English Heritage (EH6199).

Research Team

Project Lead/Principal Investigator: Professor Gareth Jones – University of Bristol (UoB)
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Subcontractors

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Project Steering Group

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Stephen Thorp – Church of England
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Simon Marks – Coordinator with Ecclesiastical Architects and Surveyors Association

Project background

Under Defra grant WM0322 a team of researchers from the University of Bristol performed experimental studies (in 2011-2013) testing deterrents to relocate Natterer's bats *Myotis nattereri* away from areas within churches in Norfolk where they were causing problems (Zeale *et al.* 2014). Key findings of that research were:

- British populations of Natterer's bats are important in an international context (Stebbings 1993), therefore exclusion of bats from churches may have serious consequences for local populations if they are not able to locate suitable alternative roosts quickly. If this results in a reduction in productivity or adult survival, models suggest this could negatively impact population growth (and Favourable Conservation Status).

- Although 180 Natterer's bats at 10 churches were radio tagged over three seasons, only one roost that might be suitable as an alternative maternity site was located in the surrounding landscape, highlighting the importance of these churches as roosting sites.

- Acoustic deterrence (high intensity ultrasound) was effective at excluding Natterer's bats from targeted roosts sites (in areas of the church where they were causing problems) and preventing them from returning. The bats were still able to utilise alternative roosts sites within the church. The use of an acoustic deterrent inside the church did not affect the home ranges, habitat preferences or nocturnal behaviour of foraging bats. Natterer's bats did not habituate to the presence of the deterrent.

- Directed use of artificial lighting to raise ambient light levels in churches is effective at excluding Natterer's bats from large areas of a church.

- Lights shone at roost entrances causes Natterer's bats to become entombed in roosts. Sustained use of lights in this way is predicted to result in the death of large numbers of bats. Unregulated use of lighting in churches, therefore, has the potential to cause serious harm to bats.

- Pipistrelles *Pipistrellus* spp. may be less deterred by lights and may habituate to this form of deterrence.

- Bats were not observed using artificial roosts (bat boxes) provided for them during experimental periods; however, some limited use was observed in subsequent years.

In addition, the response of soprano pipistrelles *Pipistrellus pygmaeus* to exclusion from maternity roosts in houses was studied at five sites in England during May-June 2012 and 2013 (when bats were in the early stages of pregnancy). Findings relevant to this study were:

- Soprano pipistrelles made use of a wide variety of alternative roosts (any roost other than that at which the exclusion was performed), some of which were clustered closely around the original colony roost (the roost from which bats were excluded), and bats switched roosts frequently. Nearly half of the alternative roosts used by bats were thought to be suitable substitute colony roosts.

- All radio-tagged soprano pipistrelle bats that were excluded found alternative roosts. There was no difference in the use of alternative roosts before and after exclusion; both the frequency of roost switching and the perceived quality of roosts used by bats remained unchanged.

- There was no evidence that exclusion had an effect on foraging behaviour; bats foraged in the same areas, travelled similar distances to reach foraging areas and showed similar patterns of habitat selection after exclusion.

- At all sites, a new colony roost was established within three days following exclusion and in each case the new roost was located within 1.5 km of the original colony roost. In all cases, the new roost had been used already as an alternative roost by one or more tagged bats during control periods prior to exclusion.

- Although no short-term change in the behaviour of bats was detected following exclusion, the long-term implications of exclusions on survival and productivity, i.e. number of female young reared, requires further investigation. Evidence from population models suggests that any reduction in survival as a result of exclusion could impact negatively on population growth. Any reduction in productivity resulting from exclusion is predicted to have little impact on populations.

Aims & Objectives

Aims

The aim of this pilot project was to use the findings from Zeale *et al.* (2014), as summarised above, to address problems caused by bats in five churches and enable churches severely affected by bats to implement cost-effective measures to prevent disruption to church use and protect its historic fabric in ways that would not be detrimental to the Favourable Conservation Status of the bats, which are protected under UK and European law.

In addition, two aspects of applying deterrents to manipulate the behaviour of bats in churches were studied to build on the research by Zeale *et al.* (2014). These were to a) investigate the impacts of deterrents on Natterer's bats in the spring, as previous experiments were conducted after young were volant in late summer and b) evaluate the effectiveness of deterring soprano pipistrelles from areas in churches where their activity and/or roosting causes problems.

The findings (based on Natterer's bats and soprano pipistrelles) together with policy advice and a licensing framework provided by Defra and Natural England, will be synthesised into a 'toolkit' to inform case-by-case management of conflict between people and bats in other churches.

Objectives

1. Significantly reduce the impact of Natterer's bats on four target churches in Norfolk while ensuring no significant impact on the bat populations concerned.
2. Determine the impact and effectiveness of deterrents in spring/early summer.
3. Investigate the effectiveness of management techniques at a church with a large soprano pipistrelle roost while ensuring no significant impact on the population concerned.
4. Refine and optimise the operation of techniques and equipment, and produce a toolkit for the effective and safe management of bats in a church context.
5. Communicate the aims, progress and results of the trial to stakeholders.

Methods

Study sites

Field research took place from May to September 2014. Research was conducted at four churches in Norfolk and one church in Northamptonshire (Table 1). All churches had medieval origins. The four church sites in Norfolk where Natterer's bats were present were selected from the 10 churches where experiments were undertaken previously by Zeale *et al.* (2014). The churches were chosen to represent a variety of building sizes and designs as well as different roost locations used within the buildings. Severity of impact was also a consideration.

Table 1. Study churches

Location	Church	Bat study species
Holme Hale	St. Andrew	Natterer's bat
Guestwick	St. Peter	Natterer's bat
Swanton Morley	All Saints	Natterer's bat
Great Hockham	Holy Trinity	Natterer's bat
Stanford on Avon	St. Nicholas	Soprano pipistrelle

Small numbers of pipistrelles also used the Norfolk study churches. Deterrents only targeted the Natterer's bat roosts. In addition, access points to/from the churches used by the pipistrelles were often different to those used by the Natterer's bats. Therefore the pipistrelles were not thought to be impacted by the deterrents or bespoke measures. At Stanford on Avon (where the aim was to determine the effectiveness of deterrent measures on the large soprano pipistrelle roost) a colony of brown long-eared bats were present in the nave roof void. This is separated from the church interior and therefore deterrent measures would not have affected the brown long-eared bat roost.

All experiments were performed under licence from Natural England and were conducted after approval by the University of Bristol Home Office Liaison Team (HOLT), the University Ethical Review Group (ERG) and after consultation with the project Steering Group.

Phase 1: Spring/early summer deterrent experiments (Objectives 2 & 3, May 2014)

Initial meetings & surveys

Before fieldwork commenced, meetings were held with Churchwardens and/or Parochial Church Council (PCC) members from each church to:

- Gain an understanding of the history of bat issues at the church and the attitude and opinions of the Churchwardens/PCC.
- Discuss the proposed research and the methods and equipment to be used in the church.
- Map the areas where droppings have been found to accumulate and areas that are particularly sensitive/prone to disruption or damage from droppings/urine (informed by the Churchwardens/PCC).

- Map the areas considered by the Churchwardens/PCC to be the most and least problematic for the roost location (i.e. their preferred location for the roost) and discuss the practicalities and attainable locations to which it may be possible to move the roost.

Initial emergence surveys were conducted at each church in early May 2014 to determine numbers of bats present, the location of roosts and entry and exit points used by bats.

Radio tagging

In May 2014, 51 adult female Natterer's bats were radio tagged at the four Norfolk churches and 18 adult female soprano pipistrelles were tagged at St. Nicholas' Church, Stanford on Avon. Numbers of tags deployed at each site are shown in Table 2. Bats were captured either by hand-netting as they exited the roost or in harp traps located inside the church. Before fitting bats with tags, bats were examined to ensure that they were in good health, met the required minimum body mass (so that tags did not exceed 7% of body mass), and were not visibly pregnant. Natterer's bats were fitted with Biotrack PicoPip Ag317, 0.46g tags and soprano pipistrelles with PicoPip Ag337, 0.32g tags (Biotrack Ltd, Wareham, UK). Tags were attached on the upper back following fur trimming and using an ostomy adhesive solution (Salts Healthcare, Birmingham, UK).

Table 2. Deployment of radio tags

Church	Species	Date of tagging	Number of tags
Holme Hale	Natterer's bat	11/05/14, 13/05/14	15
Guestwick	Natterer's bat	21/05/14	8
Swanton Morley	Natterer's bat	15/05/14	13
Great Hockham	Natterer's bat	16/05/14	15
Stanford on Avon	Soprano pipistrelle	20/05/14	18
		Total	**69**

Acoustic deterrent trials & radio tracking

Acoustic deterrent trials were carried out at each of the five study churches in May 2014 following the experimental design shown in Table 3. Acoustic deterrence consisted of a pair of 'Deaton' ultrasonic speakers (see Table 4 for further details). The speakers were placed directly underneath the main roost at table height (see Table 5 for distances from the speakers to the roosts for each church). On the first night of use (for both Phases of the project and all deterrent types) deterrents were activated after emergence (until 30 minutes after sunrise) to allow the bats to exit the targeted roost unaffected. On subsequent nights the deterrents were activated from 30 minutes before sunset until 30 minutes after sunrise (with the exception of the light deterrent used in Phase 2 at Holme Hale - see Phase 2 Results for details).

Day roosts of radio tagged bats were located (inside and outside of the churches) using an R1000 receiver (Communications Specialists Inc., USA) and a 3-element Yagi antenna and mapped on each day of the experimental trial. Functioning tags continued to be located beyond the experimental phase to monitor roost movements and to identify alternative roost sites. The locations of droppings inside the churches were also mapped. Tagged bats were classed as 'away from the church' when located in a roost outside of the church and also when no signal was detected but the bat was located on a subsequent day (ruling out tag failure, with the bat assumed to have been away from the church, beyond detection range). Tagged bats were classed as ‘no data’ when no signal was detected and the tag was not located subsequently (assumed to be tag/battery failure). Tags found detached from the bat were also classed as ‘no data’. A tag was also assumed to be detached if it remained in the roost after the usual emergence period and this was confirmed on subsequent nights. No tags were found to have remained in the roost after the usual emergence period and then to have emerged on a subsequent night.

Table 3. Experimental design of spring acoustic (Deaton) deterrent trials

Day	Period	Description
1	Post-tagging	Day following final trapping and tagging evening at church. Data not included due to potential behavioural impacts of trapping/tagging.
2	Control	Roosting locations (without any deterrents active) assessed.
3		
4		As above. Deterrent switched on after emergence.
5	Deterrent	Deterrent switched off 30 minutes after sunrise and switched on 30 minutes before sunset.
6		
7		Deterrent switched off 30 minutes after sunrise, not activated at sunset.
8	Post-deterrent	No deterrents in use.
9		
10		

NB Experimental procedure applied at night and the resulting outcome (roost location) determined the following day.

Table 4. Acoustic (ultrasound) deterrent specifications (see Zeale *et al.* 2014 for further details).

Deterrent	Company	Origin	Bandwidth	Frequency	Deployment	Advantages	Disadvantages
'Deaton'	Deaton Engineering (Texas, USA)	Bat deterrent to reduce collisions at wind turbines, (Arnett *et al.* 2013).	Broadband	Broadband (20-100 kHz) but strongest at 50 kHz	In pairs at table height pointing up at roost	Powerful, can be used at table level	Expensive, heavy, large, requires relay box and transformer, very audible to humans
'CR'	Concept Research Ltd (Hertfordshire, England)	Prototype developed in collaboration with the Zeale *et al.* (2014) project as a smaller, lighter and more cost effective unit	Narrowband	Constant frequency cycling between 40 and 60 kHz	In threes c. 1.5m below roost pointing upwards	Small, lightweight, cheaper	Lacks power, needs to be placed close to roost (access difficulties)

Table 5. Distances from acoustic (Deaton) deterrents to roosts (to the nearest 0.5 m) used in the Phase 1 acoustic deterrent trials.

Church	Acoustic deterrent location	Distance deterrent to roost (m)
Holme Hale	Nave – west end	11.0
Guestwick	Nave – east end	9.5
Swanton Morley	Nave – east end	13.5
Great Hockham	North aisle – west end	4.5

Phase 2: Developing and refining techniques (Objectives: 1, 3 & 4, June-Sept 2014)

Once the Phase 1 trials were complete, the study entered a more responsive and dynamic phase, with different measures implemented at each church depending on the evolving situation and responses of bats to deterrents. By the end of Phase 1, Natterer's bats at the Norfolk churches were heavily pregnant and beginning to enter parturition, so trials/deterrent use were halted until Phase 2 could safely commence once the pups were volant. Pregnancy was considerably less advanced at the soprano pipistrelle roost at Stanford on Avon, therefore Phase 2 commenced immediately following the Phase 1 trials until the bats were heavily pregnant/entering parturition, when work was also halted until the pups were volant.

During Phase 2, acoustic deterrents were trialled longer-term to assess their effectiveness at reducing the impact of bats on each church (along with any potential habituation/reduction in effectiveness over time). Acoustic deterrents consisted of pairs of 'Deaton' speakers at table height (see Table 6 for distances from Deaton acoustic deterrents to roosts) and three Concept Research (CR) speakers positioned c.1.5m below the roost site (see Table 4 for acoustic deterrent specifications). In addition, artificial light deterrents were tested with both Natterer's bats and soprano pipistrelles with the aim of creating 'no fly zones' to reduce dropping/urine scatter from flying bats. The light deterrents consisted of a set of two halogen work lamps (120-400 watt 'EcoHalo' bulbs used) positioned 1.5-2m above ground level. Position, angle and direction of the lights were adjusted on a day-to-day basis according to findings.

Table 6. Distances from acoustic (Deaton) deterrents to roosts (to the nearest 0.5 m), used in Phase 2.

Church	Acoustic deterrent location	Distance deterrents to roost (m)
Holme Hale	n/a	n/a
Guestwick	Nave – east end	9.5
	Nave – west end (south side)	8.5
Swanton Morley	Nave – east end	13.5
Great Hockham	Nave – central	10.5

Use of both deterrent types was refined and optimised during this phase of the project. Additional 'bespoke' measures, tailored to the church, were implemented at Holme Hale for testing to improve on the desired outcome of reducing the impact of bats on churches while ensuring no significant impact on the bat populations concerned.

Each study church was closely monitored with regular emergence counts (at least once per week) to assess numbers of bats and exit/entry points using Batbox III D heterodyne bat detectors (Batbox Ltd., Steyning, England), night vision monoculars (Yukon Advanced Optics Worldwide, Vilnius, Lithuania) and a Canon XA10 infrared video camera (Canon Europe Ltd., Uxbridge, England) used with infrared floodlights. The infrared camera and floodlights were provided by Philip Parker Associates. Droppings and roost locations (determined from dropping accumulations and audible bat social calls) in response to deterrents/bespoke measures were mapped daily. Additional targeted emergence surveys (concentrating on a specific area of a church/exit point) and dawn surveys were used to gain further information on how the bats were using each church and responding to deterrents/bespoke measures. Only complete (whole church) emergence survey data are presented in this report. Generally, dawn surveys are considered to provide less accurate counts (due to considerable swarming activity and bats entering and exiting during this period) but were of value when determining entry points (especially when these differed to preferred exit points) and locating access points that were used infrequently.

Some further late summer radio-tagging was undertaken at Holme Hale (10 adult females tagged) to improve monitoring of bespoke measures and at Great Hockham (four adult females) to gain additional information on the location of alternative roosts due to the absence of the maternity colony (see Results below).

Bat boxes

Bat boxes, positioned both inside and outside the Norfolk churches in 2012 (by Zeale *et al.* 2014) and in the tower at Stanford on Avon in 2011 (by STJ Contractors under a watching brief from BSG Ecology), were checked regularly for occupancy and signs of use. Towards the end of the field season (late August 2014), a large, heated bat box was temporarily installed on the church exterior at Stanford on Avon, adjacent to the bats' entry/exit point, in addition to an unheated box positioned in a large oak tree opposite.

Results

Phase 1: Spring/early summer deterrent experiments

Natterer's bats

The responses of Natterer's bats to the Deaton deterrents in spring was strong and comparable to that observed in late summer by Zeale *et al.* (2014). Data combined for the four churches (*n* = 51 bats, Figure 1) show that 63-75% of the bats used the original roost site in the church during the three control days (deterrent off), with 10-20% roosting at an alternative location in the church and 4-14% roosting outside of the church. On the first day following night time application of the deterrent, the proportion of bats at the original roost site (below which the deterrent was applied) fell to 18% and subsequently to 2% and then 0% on the second and third deterrent days respectively. The percentage of bats using alternative roost sites in the church increased correspondingly, 67-71%, whilst those roosting outside of the church remained similar to pre-deterrent numbers (8-18%). Post-deterrent, some bats returned to the original roost, but numbers were reduced considerably compared with the control period (22-31%), although it should be noted that tags for which no signal could be detected, classed as 'no data', had reached 37% by the third post-deterrent day, probably due to failed tags. Only one of the roosts located away from the churches (linked to Great Hockham) was considered to have potential as a major alternative roost, with 19 bats recorded emerging (emergence counts were conducted at any roosts used by more than one tagged bat - Table 7).

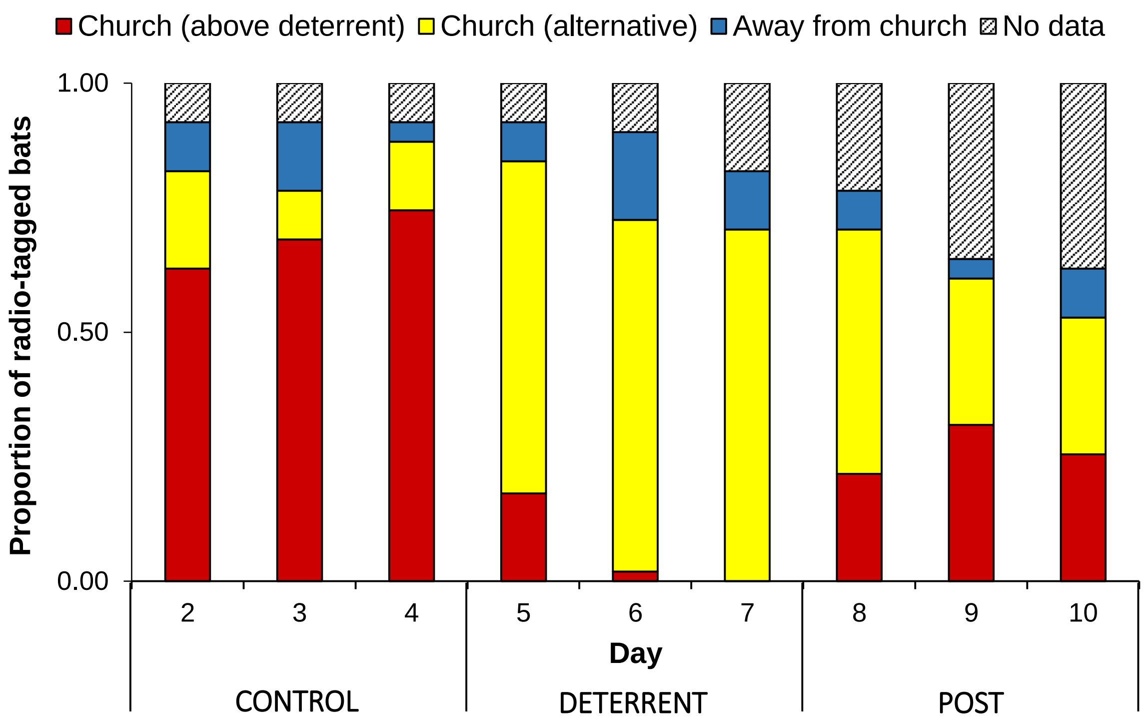

Figure 1. Mean proportion of radio-tagged Natterer's bats (*n* = 51, all four churches combined) roosting in the church at the original roost (above the deterrent), at an alternative location within the church and away from the church (as well as those tags for which no data were received) during control (deterrent not switched on), 'deterrent' (deterrent switched on) and 'post' (deterrent switched off) stages.

Table 7. Occurrences of bats roosting outside of the churches during the nine day spring radio-tracking deterrent trials (control, deterrent and post-deterrent stages). The total number of occurrences of bats roosting outside of each church (*n*) is given along with the number of occasions that a bat was found in a particular roost type.

Site	*n*	Tree	Building		Unknown	Alternative colony roosts (with max count)
			Uninhabited	Inhabited		
Holme Hale	14	7			7	
Guestwick	12	3	1		8	
Swanton Morley	5	1			4	
Great Hockham	13	11*			2	1 (19)
Total	44	22	1		21	
Stanford on Avon	29			4	25	1 (286)

*Roost shared simultaneously by at least two tagged bats on at least one occasion

Soprano pipistrelles (Stanford on Avon)

The soprano pipistrelles also exhibited a strong response to the Deaton deterrents during the spring trials (Figure 2), following a similar pattern to the Natterer's bats. During the control period however, alternative roosts within the church were used less (e.g. by only 17% of the tagged bats on Day 2) than by the Natterer's bats. On the first day of deterrent use, a greater proportion of soprano pipistrelles (22%) roosted away from the church compared to Natterer's bats (8%). On the second day of deterrent use no pipistrelles were using the original roost site, however on the third day a small proportion (11%) were back at the original roost. Throughout the deterrent and post-deterrent periods the majority of bats used alternative roosts inside the church. The proportion of pipistrelles using the original roost post-deterrent was lower compared to the Natterer's bats (with 17% present on the first day post-deterrent and none present on the subsequent two days of the post-deterrent stage). On 14% of occasions of bats roosting away from the church a converted (inhabited) barn in the village of South Kilworth was used (Table 5, by up to two of the tagged bats simultaneously only after the deterrent trial had finished). The barn roost is 3.4 km from the church and hosts maternity roosts of both soprano (all exit from the south-west side of the building) and common pipistrelles *Pipistrellus pipistrellus* (146 counted exiting from the north-east side). Emergence counts for the barn roost are shown in Figure 9 (with a peak count of 286 soprano pipistrelles on 31st May and 23rd July 2014).

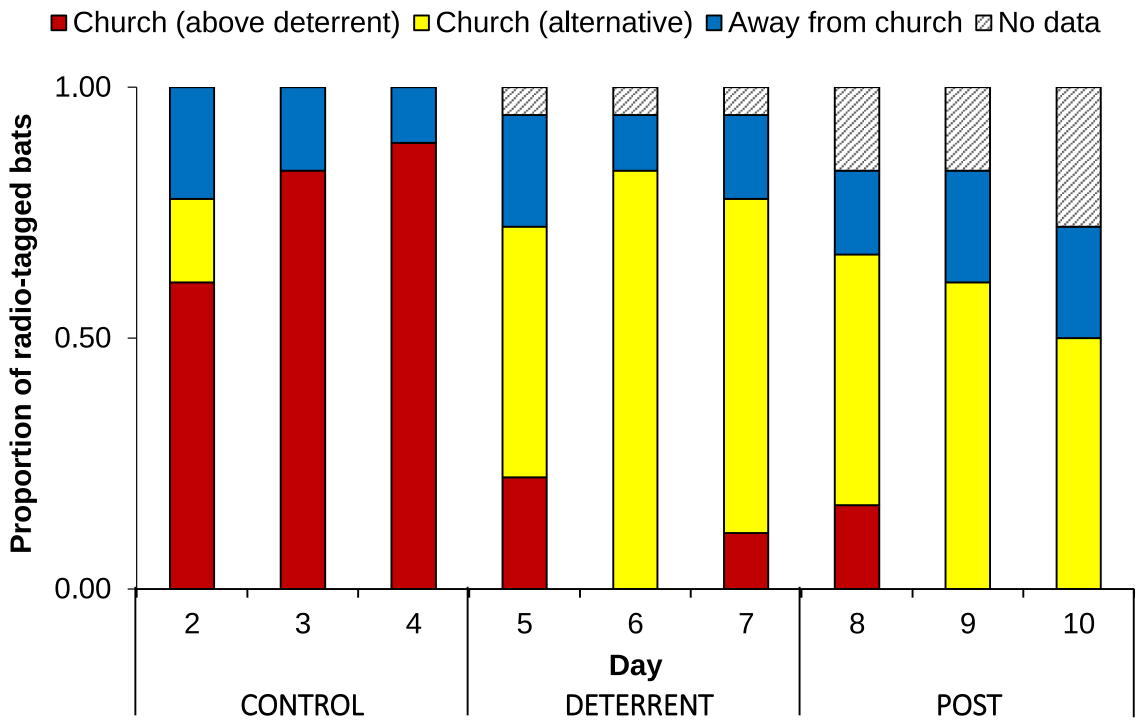

Figure 2. Proportion of radio-tagged soprano pipistrelles (Stanford on Avon, *n* = 18) roosting in the church at the original roost (above the deterrent), at an alternative location within the church and away from the church (as well as those tags for which no data were received) during control (deterrent not switched on), 'deterrent' (deterrent switched on) and 'post' (deterrent switched off) stages.

Phase 2: Developing and refining techniques

Holme Hale: bespoke measures & re-entry light deterrent (with additional radio tracking)

Holme Hale had the largest colony present (peaking at an estimated 264 Natterer's bats on 9th July 2014, Figure 3) and more than double the maximum count for the next largest Natterer's bat church roost in the study (Swanton Morley, with 112 Natterer's bats on 24th July). As such, impacts experienced at Holme Hale are particularly problematic, with bats roosting freely in the nave above the central ridge beam (Figure 4), resulting in large accumulations of droppings on the floor below and creating a substantial cleaning burden, damage to pews and church artefacts, staining of the walls and an unpleasant and potent smell. Given the large roost size (and its location, spread along the length of the nave), reducing the impact of the bats by deterrent use alone was considered unlikely to result in a significant and satisfactory improvement. Therefore bespoke measures were designed for a trial period.

Prior to implementation of bespoke measures, the west end of the north aisle was the exit point used by the majority of bats (Figure 3 & 4) and dawn surveys revealed the north and south sides of the west end of the nave to be the preferred entry points (with the north aisle exit point little used for re-entry at dawn). Internal inspection of the entry zones (the eaves of the west end of the nave) with a cherry picker revealed many small mortise joint roosts. The bespoke approach involved fixing boards at the west end of the north and south sides of the nave, 'boxing-in' the eaves' void for 5m on both sides and encompassing the two major entry points (Figure 4 & 5, see Appendix 1 for further details). As a result, the entry points (and lesser-used exit points) to the church would remain unaltered, but on entry the bats would be contained within a large roosting area (on both sides), sealed off from the rest of the internal space of the church, and which encompassed the mortise joint roosts.

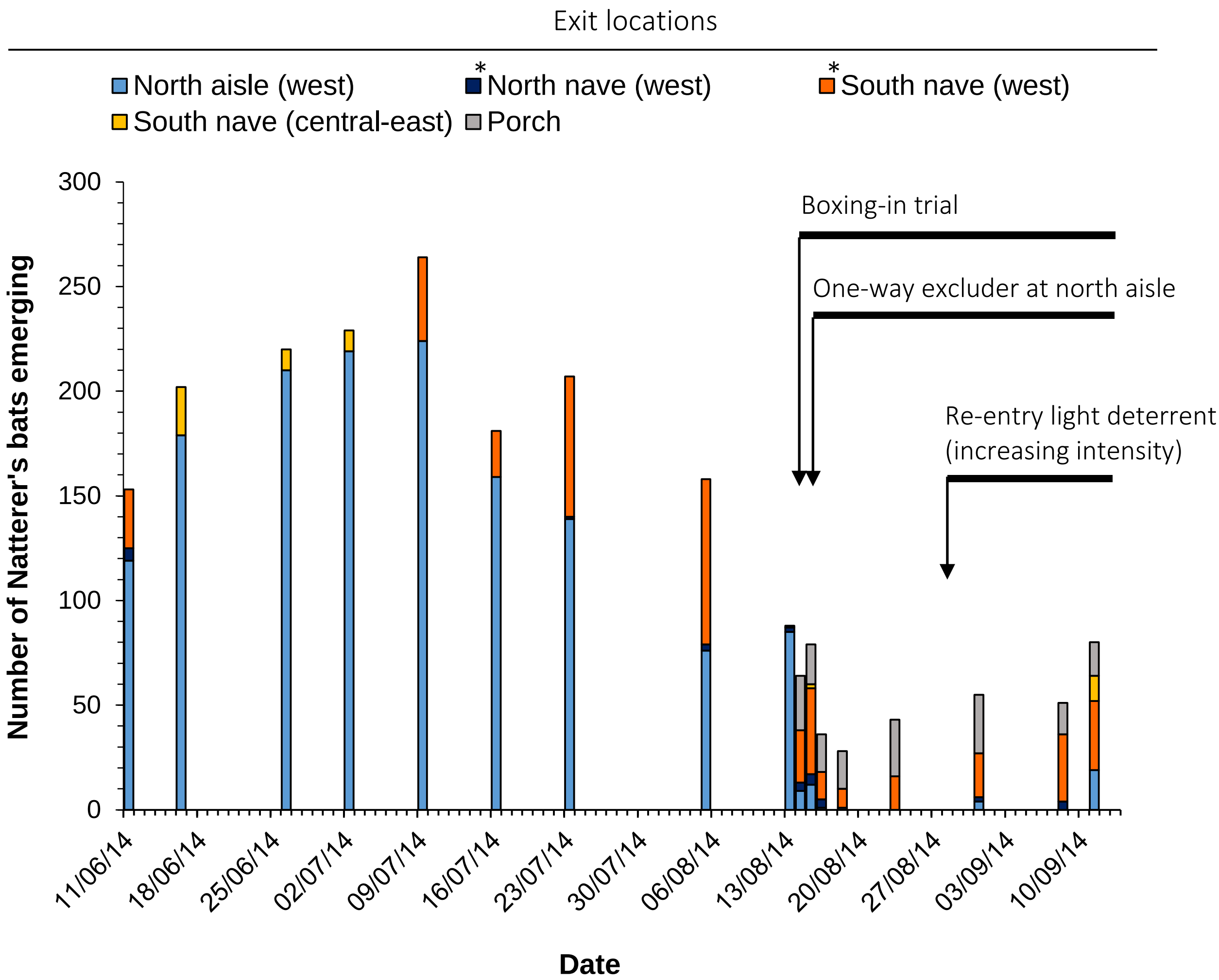

Figure 3. Complete (whole church) dusk emergence counts showing numbers of Natterer's bats emerging from different exit points at Holme Hale Church, along with application of late season bespoke measures (boxing-in trial), one-way exclusion device at the north aisle and re-entry (post-emergence) light deterrents of increasing intensity. During the boxing-in trial, all bats exiting from 'south nave (west)' and 'north nave (west)' came from the south and north nave boxed-in areas respectively (exit locations marked with an asterisk in the figure legend).

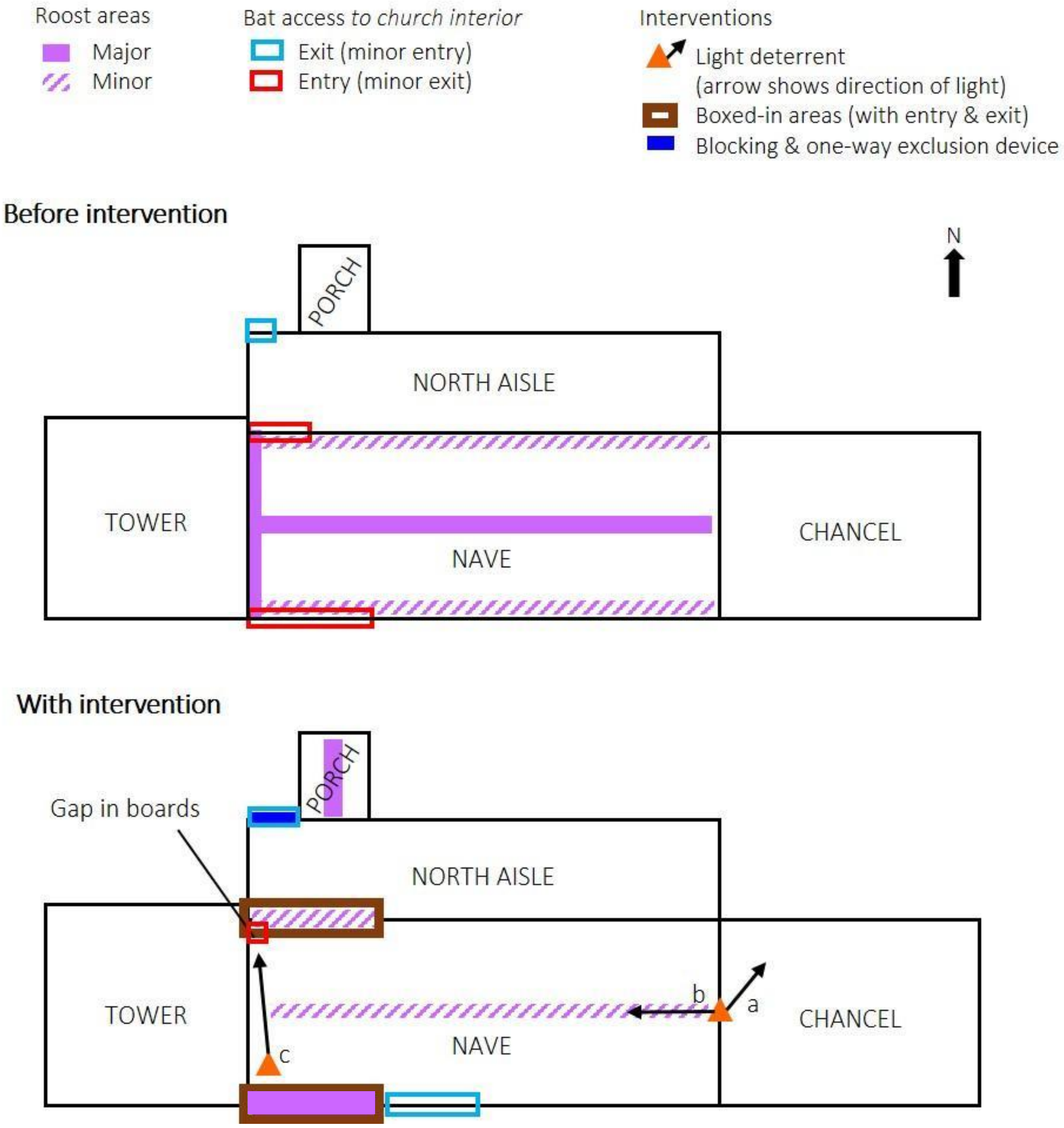

Figure 4. Simplified plan of Holme Hale Church (not to scale) showing main roost areas, entry and exit points to/from the church interior as well as the location of the boxed-in areas and light deterrents (Phase 2). Letters indicate different light set-ups used.

Left: nave eaves void areas to be boxed-in (north and south sides) circled in blue. View from the chancel.
Above: South nave eaves void area to be boxed-in.

View inside the south nave boxed-in area. A mortise joint roost is circled in red.

Temporary boards forming the south nave boxed-in area, viewed from the west end of the nave.

Figure 5. Images showing the temporary boxing-in trial at Holme Hale.

Two days prior to the installation of the temporary boards, 10 adult female Natterer's bats were radio-tagged. On 13th August 2014 the temporary (hardboard) boards were installed during the day (using a cherry picker, see Appendix 1 for details). The bats were closely monitored subsequently, with an intensive period of both dusk and dawn surveys (with internal and external observers) and locating the day roosts of the 10 tagged bats, to assess the effects of the boxing-in trial. The boxed-in areas were assessed for a period of 30 days and removed from the church on 7th October 2014.

By the date of the boxing-in trial, numbers of bats roosting at the church had already decreased considerably (down to 88 bats the day before the boards were installed), as expected at this time of year when bats are usually moving away from the maternity roost (Figure 3). Numbers initially decreased further during the trial, although were back to preboxing-in numbers by the last emergence count of the trial (28 days after installation of the boards). South and north side exits of the west end of the nave were encompassed by the boxed-in areas (Figure 4), and so all bats exiting from these locations must have been roosting within the boxed areas. A one-way exclusion device was fitted to the north aisle exit point (the preferred exit) to allow any bats within the body of the church to exit but prevent re-entry at this point. However, this was not entirely successful as the bats were subsequently found to exit/enter from a number of points at the west end of the north aisle (along a section several metres long), in addition to using the one-way exclusion device to exit.

Up to 46 bats were found to be using the boxed areas at any one time, with up to 41 in the south nave boxed area, but only five used the north nave boxed area. The scattering of urine across the entire length of the paper lining the floor of the boxed-in areas was evidence that the bats were able to fly within the boxed-in areas. The north nave boxed area was subsequently discovered to have a gap through which the bats could still enter into the body of the church (to access the original roost above the central ridge beam of the nave), and dawn surveys with an internal observer revealed that almost all of the small numbers of bats that still managed to gain entry to the interior did so via this point (these bats exited from the north aisle and south nave (central-west)). In addition, up to 28 bats adopted the porch as a new roost site. This was considered to be a favourable, low impact location, as bats in the porch were not accessing the church interior and droppings/urine deposition in the porch was minimal.

Once it became evident that some bats were still gaining access to the church interior through a gap in the north nave boxed area, the light deterrent was used for a period of 13 days to test its potential for deterring re-entry into the lit interior of the church at dawn (and also as it was not possible to repair the gap within the timeframe of the trial as it would have required hire of a cherry picker). As the boxed areas were enclosed they would remain dark (as would the porch roost). The light deterrent was switched on from two hours after sunset (after all bats had emerged) until 30 minutes after sunrise. Light levels were gradually raised throughout this period (as no effect on the bats was observed), starting with the lights positioned in the chancel facing away from the body of the church (Figure 4, light deterrent set-up ‘a’), to the final stage, with the lights at the west end of the nave, pointing directly at the re-entry point gap in the north nave boxed area (Figure 4, light deterrent set-up ‘c’). Care was taken to minimise light spill from the windows, to avoid raising external light levels, especially around roost entry/exit points to the desired locations of the south and north nave boxed areas and the porch. Even with the interior access point and original roost (above the central ridge beam of the nave) brightly lit in the final stage, some bats continued to enter the body of the church at dawn and behaviour appeared unaffected. This was in stark contrast to the effect of the light deterrent when applied prior to emergence (30 minutes before sunset) at Swanton Morley (see below). At the final emergence count, the proportion of bats gaining access to roost in the church interior at Holme Hale had risen to 39% (prior to this it was 3-7%; following installation of the 1-way excluder at the north aisle).

Prior to the installation of the boxed-in areas, seven of the 10 radio-tagged bats roosted in the main body of the church, with three roosting outside of the church (Figure 6). Once the boards were installed, the boxed areas were used regularly by individual tagged bats and up to four of the tagged bats roosted in the porch at any one time (with always at least one tagged bat present). A greater proportion of the tagged bats roosted away from the church after the boards were installed. On 80% of occasions, roosts located outside of the church were in trees (five different oak trees located in Necton Common, two beech trees, one poplar and one Scots pine) and 20% of occasions involved bats using a small bat box in an uninhabited, dilapidated barn, 300 m from the church. The barn was used simultaneously by two of the tagged bats. An emergence count at the barn was hampered by bad weather conditions but a minimum of 15 Natterer's bats were recorded. Of the nine different tree roosts found, three were utilised simultaneously by more than one tagged bat on at least one occasion and one of these was utilised by half of the tagged individuals at some point during the radio tracking period (an old beech tree on private property, 60 m from the church). Tags began to fail ('no data') from 11 days post-tagging, with the number of failed/detached tags increasing until day 26 when the last remaining tag could not be detected (Figure 6).

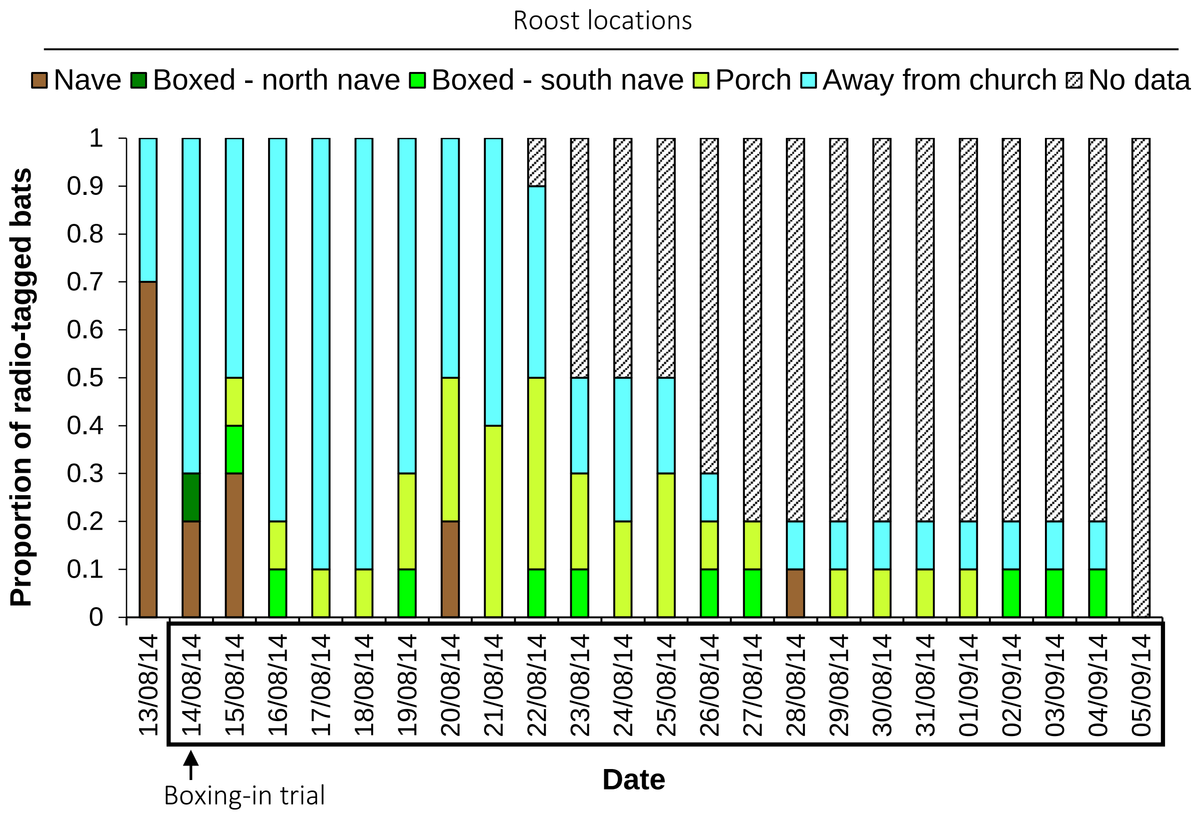

Figure 6. Day roost locations of 10 adult female Natterer's bats during the boxing-in trial. Bats were caught exiting the church and radio-tagged on 11/08/14. The nave is the only location where the bats were roosting inside the main body of the church. The 'boxed – north nave', 'boxed – south nave' and porch roosts (as well as 'away from the church') were roost locations without bat access into the interior of the church.

Guestwick: acoustic deterrents (Deaton and trial of CR)

Numbers of Natterer's bats roosting at Guestwick Church did not decline through August and September, as observed at the other churches, with the final count on 10th September being the fourth highest for the church (48 Natterer's bats, Figure 7). Use of the Deaton deterrent for 37 days and the CR deterrent for 10 days did not appear to impact on numbers of bats roosting at the church. A pair of Deaton speakers was positioned at table height below the original roost in the chancel arch (Figure 8 and 9). Few or no droppings were found at this location subsequently (37 days). The main roost was then located at the south side (west end) of the nave (where previously only limited use by bats was recorded), where a second pair of Deaton speakers was subsequently installed (Figure 7) . The volume of droppings that accumulated at this location was greatly reduced by the presence of the deterrent. Visual inspections revealed a small number of bats using the roost, which had shifted approximately 2m west, out of the direct line of the deterrent. After 12 days the Deaton speakers were replaced by three CR speakers, attached to a ladder and positioned approximately 1.5 m below the roost (Figure 9). The remaining bats roosting just west of this location subsequently left (day 1 following installation) and the CR speakers successfully prevented the return of Natterer's bats to roost at this location.

From this point on the location of the main roost was not evident and few droppings were found inside the church. However emergence counts were not affected, and so evidently the bats were still present but roosting elsewhere in the church. Subsequent investigation by a dawn survey with internal and external observers revealed that 53 Natterer's bats entered the church under the chancel eaves on the south side, however none passed through to the interior of the church. Inspection of the interior eaves' void of the chancel confirmed this. Bats were heard on the exterior side of the eaves' void boards. The majority of bats now roosted in the outer section of the south chancel eaves (Figure 9). Therefore all bats counted emerging from the chancel (south) in Figure 7 were assumed to be roosting here without accessing the interior of the church.

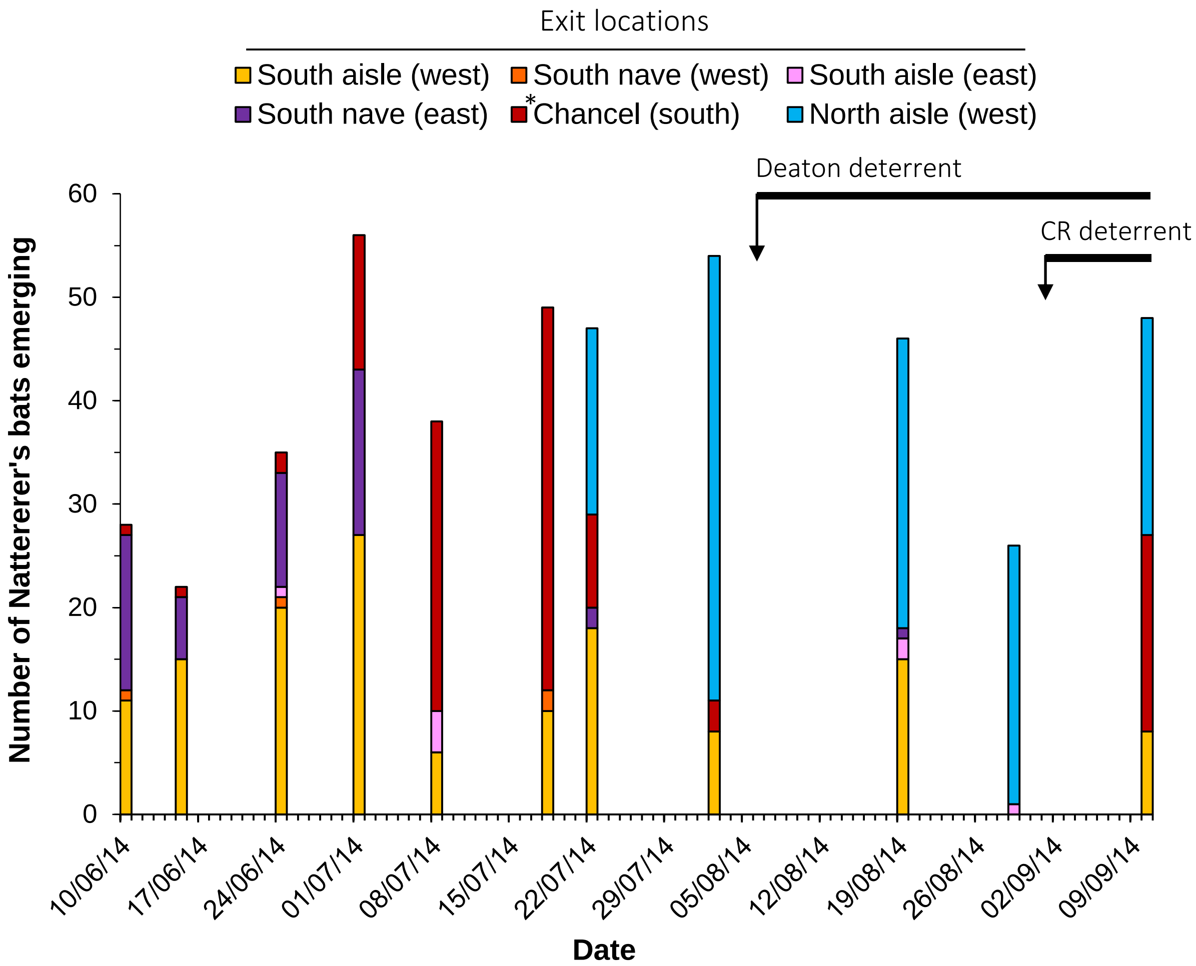

Figure 7. Complete (whole church) dusk emergence counts showing numbers of Natterer's bats emerging from different exit points at Guestwick Church, along with application of acoustic deterrents: pairs of Deaton speakers and a set of three CR speakers. Note bats emerging from 'Chancel (south)', marked with an asterisk, were considered to be utilising a roost separate from the church interior.

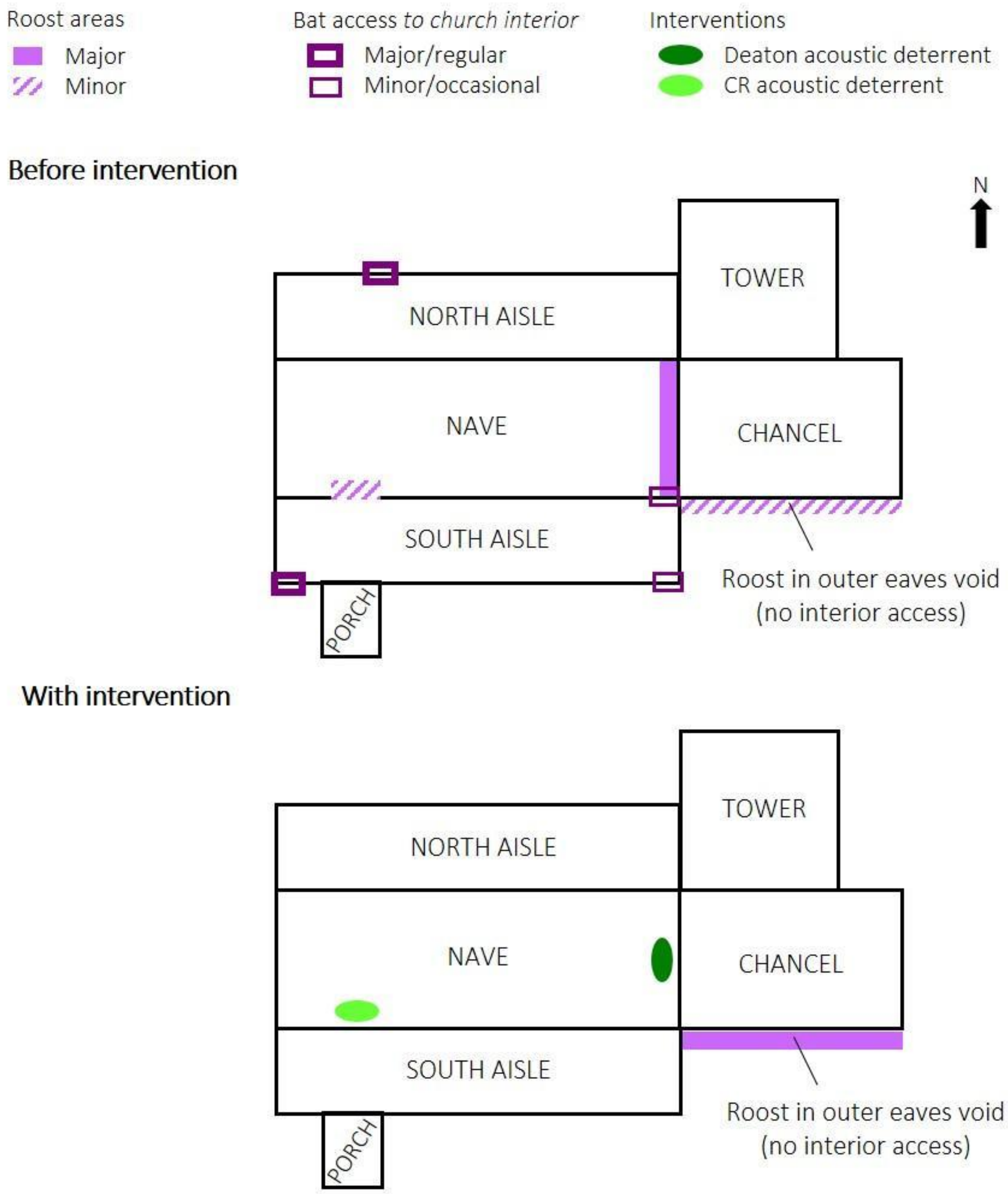

Figure 8. Simplified plan of Guestwick Church (not to scale) showing main roost areas and bat access points to/from the church interior as well as the location of acoustic deterrents (Phase 2).

Figure 9. Phase 2 acoustic deterrent use at Guestwick Church. A pair of Deaton speakers under the original nave (east end) roost (top left), three CR speakers attached to a ladder to temporarily raise them to 1.5m below the next roost location, at the west end (south side) of the nave (top right), Natterer's bats inside the roost at the west end of the nave (bottom left) and the final roost location in the outer void of the south chancel eaves (bottom right). Roost locations circled in red.

Swanton Morley: acoustic & light ('no fly zone') deterrents

At the beginning of Phase 2 the roost was located in the chancel arch, with large volumes of droppings accumulating on the floor beneath the roost (Figure 11). A pair of Deaton deterrents was introduced here for a period of 32 days. The number of bats roosting at the church was not affected (Figure 10). It took six days for this roost location to be completely vacated. Subsequently the bats roosted at multiple locations in this large church, predominantly in the south aisle (mostly west end) but also at times in the west end of the nave (Figure 11).

On the 2nd-3rd September the light deterrent was trialled with the aim of creating a 'no-fly-zone' i.e. reducing pre-emergence flight (and therefore the spread of droppings and urine) in areas of the church away from the roost sites and exit. The light deterrent was switched on after emergence (two hours after sunset) on 2nd Sept until 30 minutes after sunrise on 3rd Sept. It was then activated from 30 minutes before sunset on 3rd September. The light deterrent was positioned in the north-west corner of the north aisle (Figure 11), with the lamps angled downwards and facing the corner; it was also partially screened by a pillar (Figure 12). This resulted in the west end of the north aisle and the tower being lit brightly, whilst the south aisle and nave were only subject to low levels of light and the chancel (exit point) was dark (Figure 12). No bats emerged from the church and internal observations confirmed only very brief bat activity from two individuals which failed to exit and returned to roost. Two hours after sunset, when all Natterer's bats would usually have exited the church, the light deterrent was switched off. In less than one minute there was considerable Natterer's bat activity within the church and 86 bats subsequently exited the church in a period of only 29 minutes (mean emergence duration for Swanton Morley (time between the first and last bat emerging) was 48 minutes, range 36-71 minutes). With these findings, use of the light deterrent was discontinued due to the high risk of entombing bats in their roost.

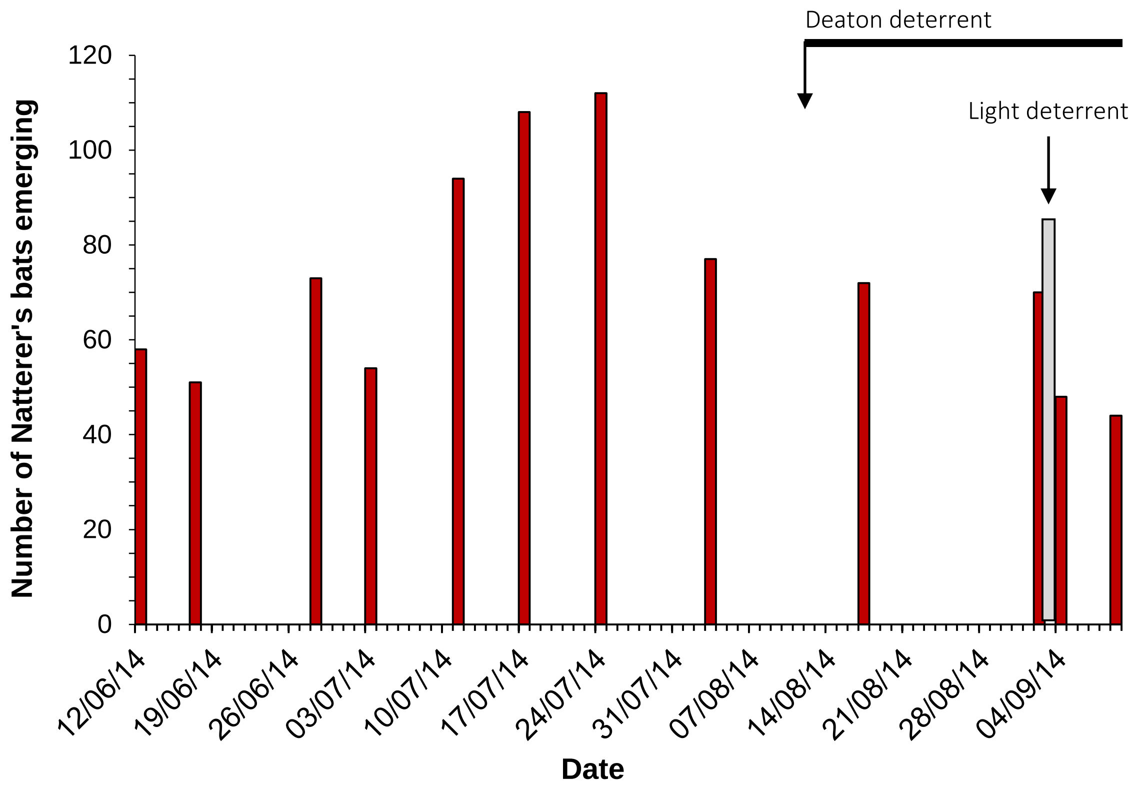

Figure 10. Complete (whole church) dusk emergence counts showing numbers of Natterer's bats emerging from Swanton Morley Church (all from the south side of the chancel), along with application of a pair of Deaton speakers and a light deterrent. The grey bar shows the number of bats that exited after the light deterrent was switched off (two hours after sunset).

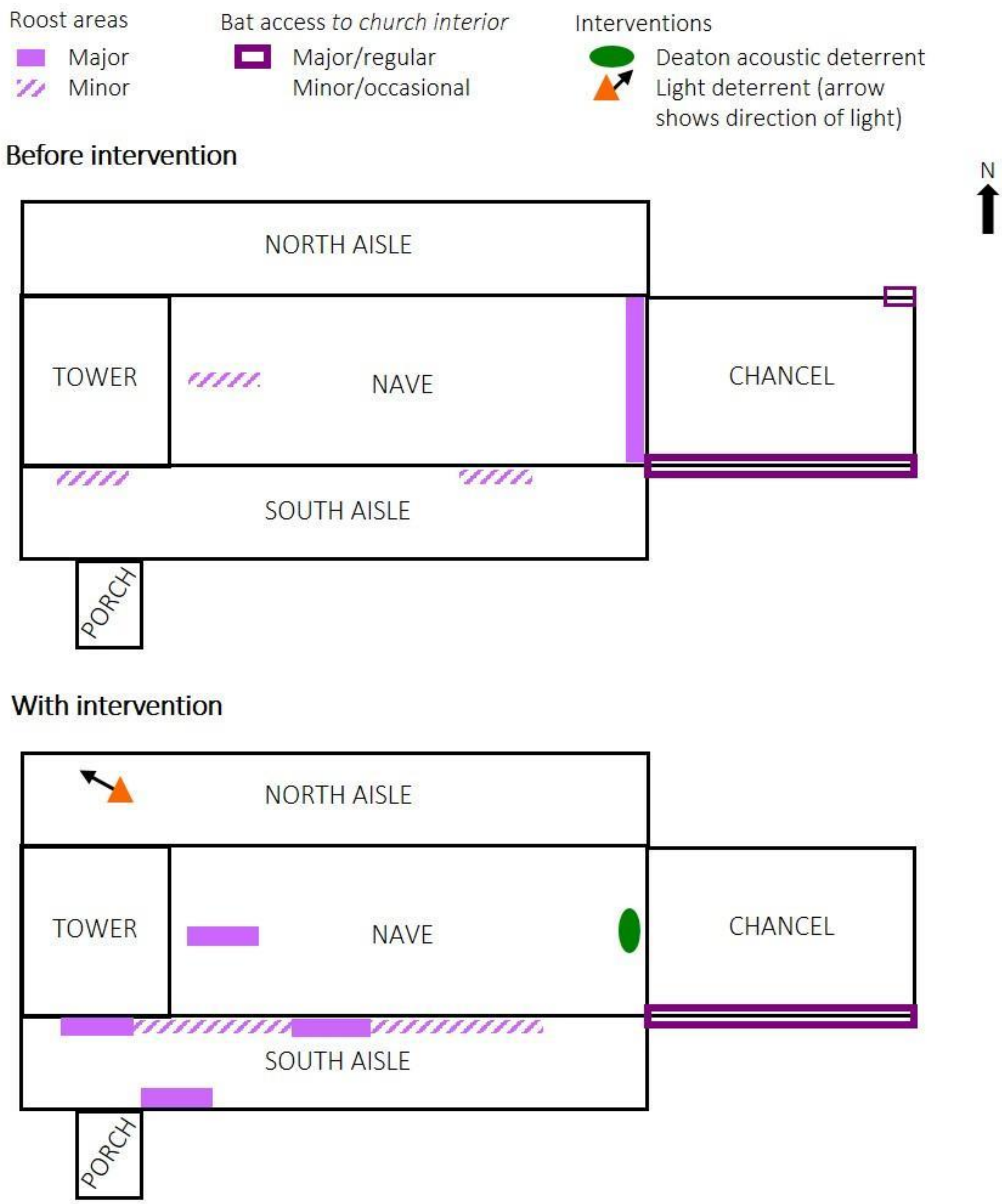

Figure 11. Simplified plan of Swanton Morley Church (not to scale) showing main roost areas, bat access to the church interior as well as the location of acoustic and light deterrents (Phase 2).

Figure 12. Light deterrent at Swanton Morley Church viewed from the chancel arch (left) and close-up of the deterrent in the west corner of the north aisle (right).

Great Hockham: acoustic deterrents (with additional radio tracking)

Unexpectedly, most of the colony at Great Hockham Church left in early June, prior to the trialling of deterrents, with fewer than ten bats remaining (Figure 13). Hand netting revealed these comprised five adult females (of which only two were lactating) and three adult males. An emergence count at the alternative roost (a silver birch tree) located during the spring radio tracking yielded only two Natterer's bats, so clearly the colony had not relocated there. In early July the volume of droppings accumulating began increasing and a count on 7th July revealed 87 Natterer's bats present (highest count recorded for this church during the project). Six hand-netted individuals caught on 28th July consisted of three adults (two male, one female) and three juveniles (two male, one female). Throughout this period all bats used exit points on the north side of the church, with the preferred exit at the east end of the north aisle (Figure 13).

For Phase 2 measures at Great Hockham, Deaton deterrents were applied for a period of 35 days in August-September, once pups were volant. A pair of speakers was located under the main roost, at this time situated in the centre of the nave (Figure 14), where droppings were accumulating on the floor. As observed at the other churches, and expected at this time of year, emergence counts at the church were gradually decreasing. This did not appear to be affected by the presence of the deterrents. Mapping of the location and abundance of droppings showed a decrease in the amount of droppings accumulating around the deterrent and was therefore indicative of a reduction in the number of bats roosting at this location. By day 8 this had reduced to no droppings found in this area. Throughout this period the roost locations shifted, with roosts occurring at many (previously used) locations throughout the church, but with the area above the deterrents rarely used by roosting bats (Figure 14).

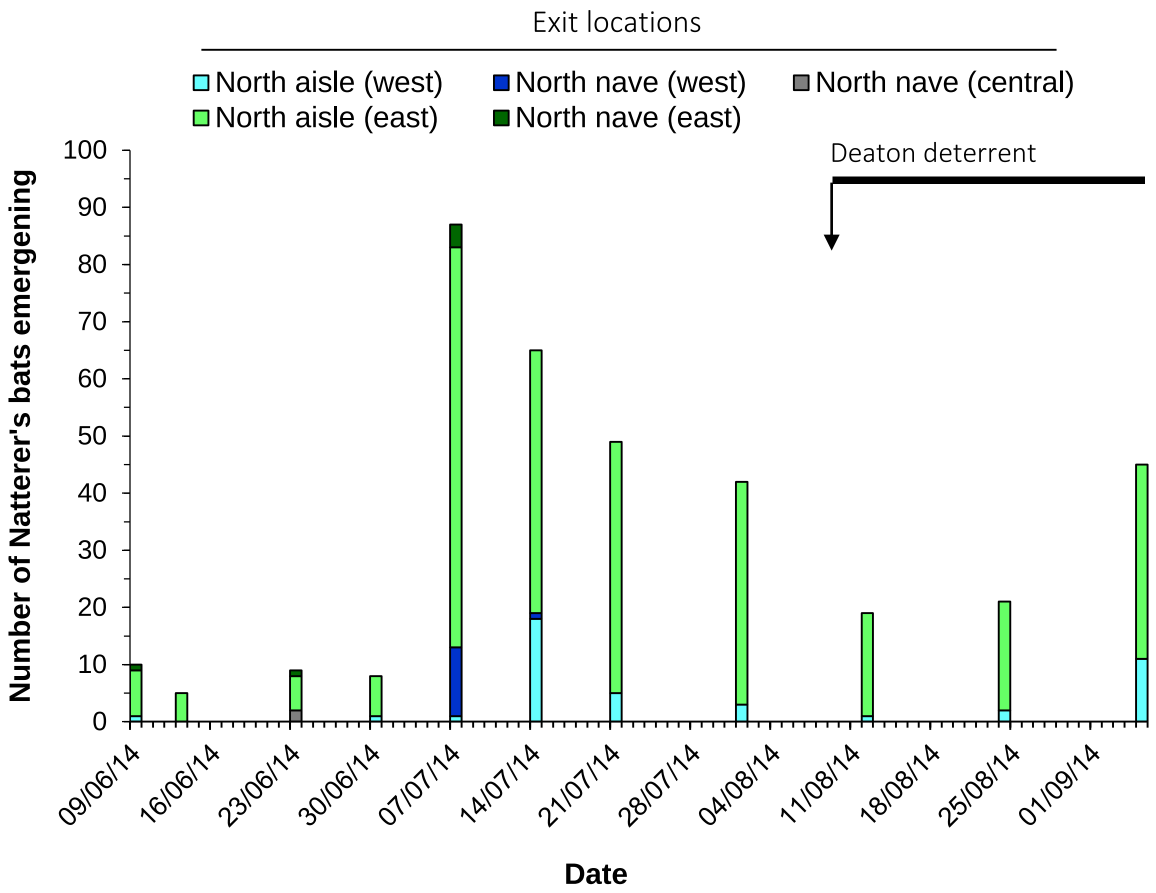

Figure 13. Complete (whole church) dusk emergence counts showing numbers of Natterer's bats emerging from different exit points at Great Hockham Church, along with application of the Deaton deterrent.

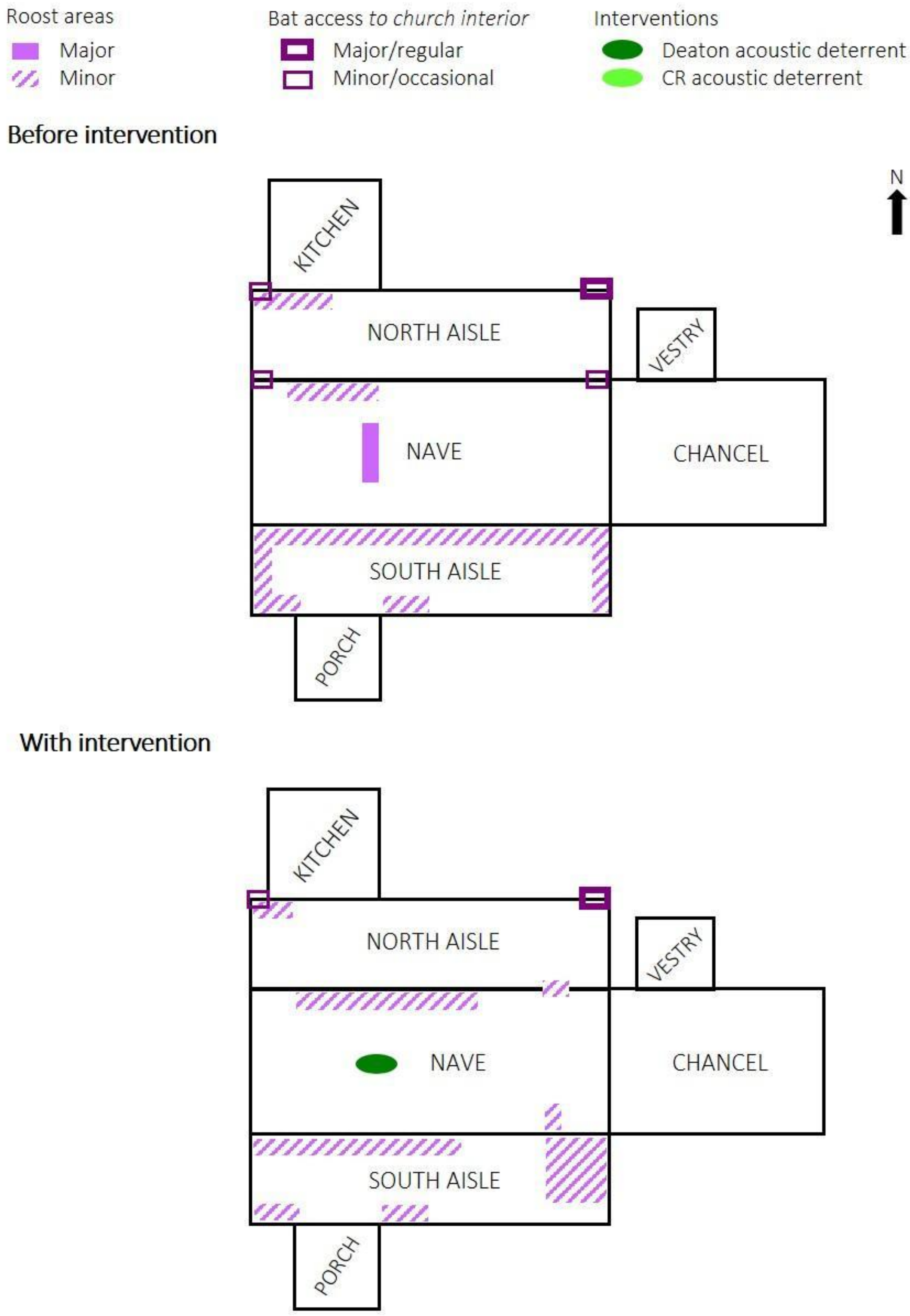

Figure 14. Simplified plan of Great Hockham Church (not to scale) showing main roost areas, bat access points to the church interior as well as the location of acoustic deterrents (Phase 2).

With the absence of most of the bats from the church during June (and therefore the alternative maternity roost site unknown), improving understanding of alternative roosts used by the Great Hockham Natterer's bats was a priority. Therefore a further four adult females were radio-tagged on 6th August 2014. On 43% of occasions the tagged bats were in the church, 32% outside of the church in a tree roost (compared to only 10% of occasions when bats roosted away from the church during the spring deterrent trials) and 25% not found (Table 8). Emergence counts were conducted at roost trees at the time of occupation, but none of the five tree roosts identified represented major roosts (with bats roosting singularly or in pairs). The closest tree roost was located in the churchyard, the most distant at 2.7 km from the church (all alternative roosts located are mapped in Figure 15). Nine of the 12 tree roosts identified by Zeale *et al.* (2014, in September 2013) and this project (May and August 2014) were located in the Hockham Block of Thetford Forest. The mapped locations, coordinates and species of the tree roosts have been given to The Forestry Commission to aid protection and management.

Table 8. Day roost location types of four adult female Natterer's bats caught and radio-tagged at Great Hockham Church (6th August 2014).

Date	Tag frequency			
	173.286	*173.314*	*173.833*	*173.960*
07/08/14	Church	Church	Not found	Tree (silver birch)
08/08/14	Church	Not found	Not found	Church
09/08/14	Tree (ash)	Tree*	Tree (oak)	Tree (sycamore)
10/08/14	Church	Tree (lime)	Not found	Church
11/08/14	Church	Tree (lime)	Tree (oak)	Church
12/08/14	Church	Tree (lime)	Not found	Church
13/08/14	Church	Church	Not found	Not found

*Exact tree could not be determined

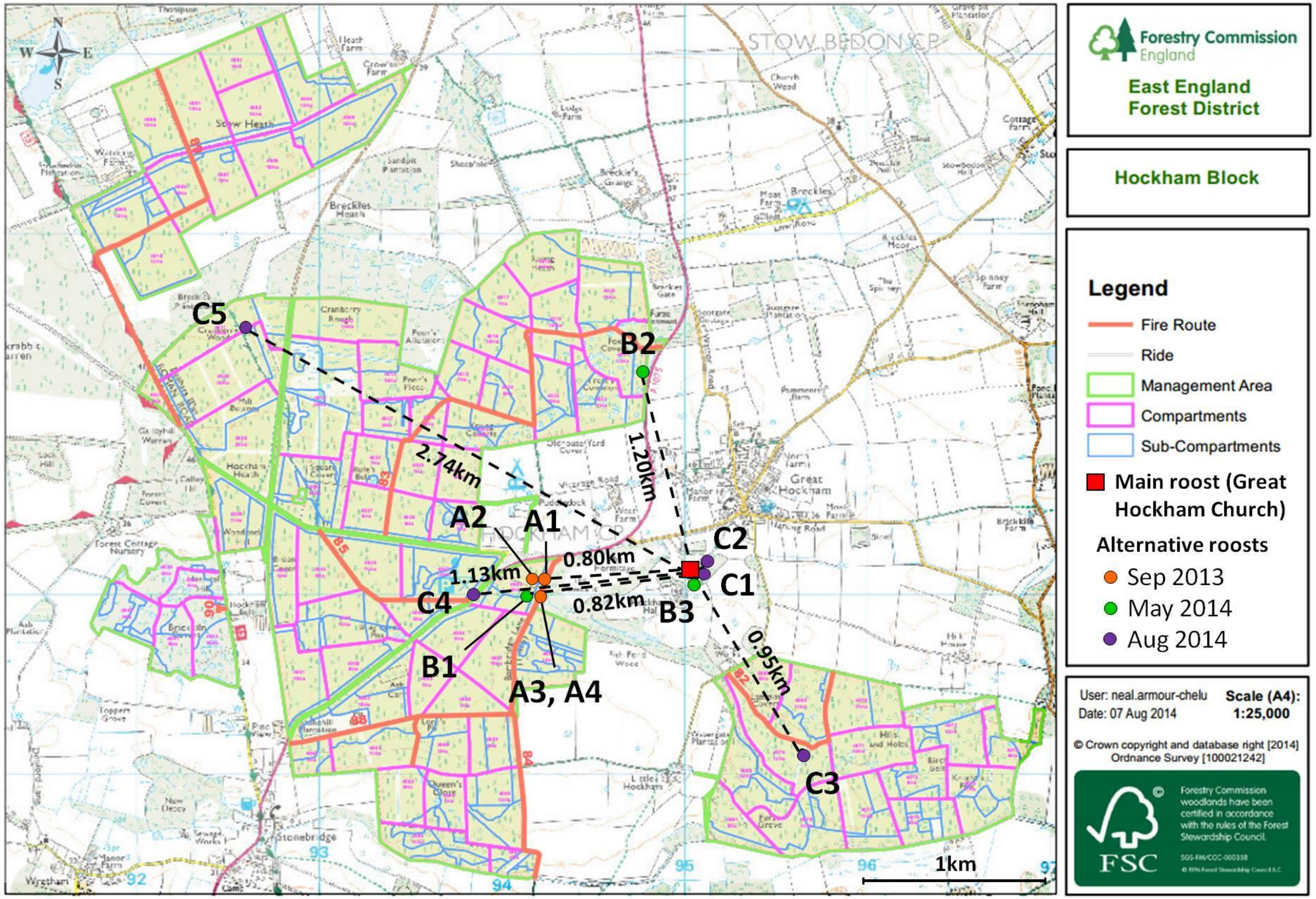

Figure 15. Alternative day roosts used by adult female Natterer's bats radio-tagged at Great Hockham Church, September 2013 (from Zeale *et al.* (2014), *n* = 10 bats tagged, four roosts located (A)) and May (*n* = 15 bats tagged, three roosts located (B)) and August 2014 (*n* = 4 bats tagged, five roosts located (B)) marked on a forestry base map provided by Neal Armour-Chelu (The Forestry Commission). Dashed lines are labelled with the distance from the main roost (Great Hockham Church) to the alternative roost location.

Stanford on Avon (soprano pipistrelles): acoustic and light ('no fly zone') deterrents

Emergence counts were conducted on 92 out of the 103 nights of Phase 2 at Stanford on Avon Church and on 19 nights (when access allowed) at the alternative roost in the converted barn in South Kilworth (Figure 16). During Phase 2, a pair of Deaton deterrents was positioned at the east and at the west end of the south aisle (the main roost locations at that time) for five nights (01/06/14 - 05/06/14), with an additional two speakers added at the centre of the south aisle after two days, for a further three nights (Figure 17). Despite the presence of three pairs of deterrents in the south aisle, the bats continued to roost here (although emergence count numbers dipped). At this point deterrent trials were paused for the maternity period because the roosts were still located directly above the deterrents.

Deterrent trials were resumed once the pups were volant and no more grounded pups were observed. Deaton speakers were positioned in the south aisle for a continuous period of 25 days (19/08/14 - 12/09/14), with 3-4 speakers positioned in the south aisle (Figure 17). Bats continued to roost above the deterrents in the south aisle; however emergence count numbers fell during this period, as also occurred when the Deaton deterrents were applied in June (Figure 16).

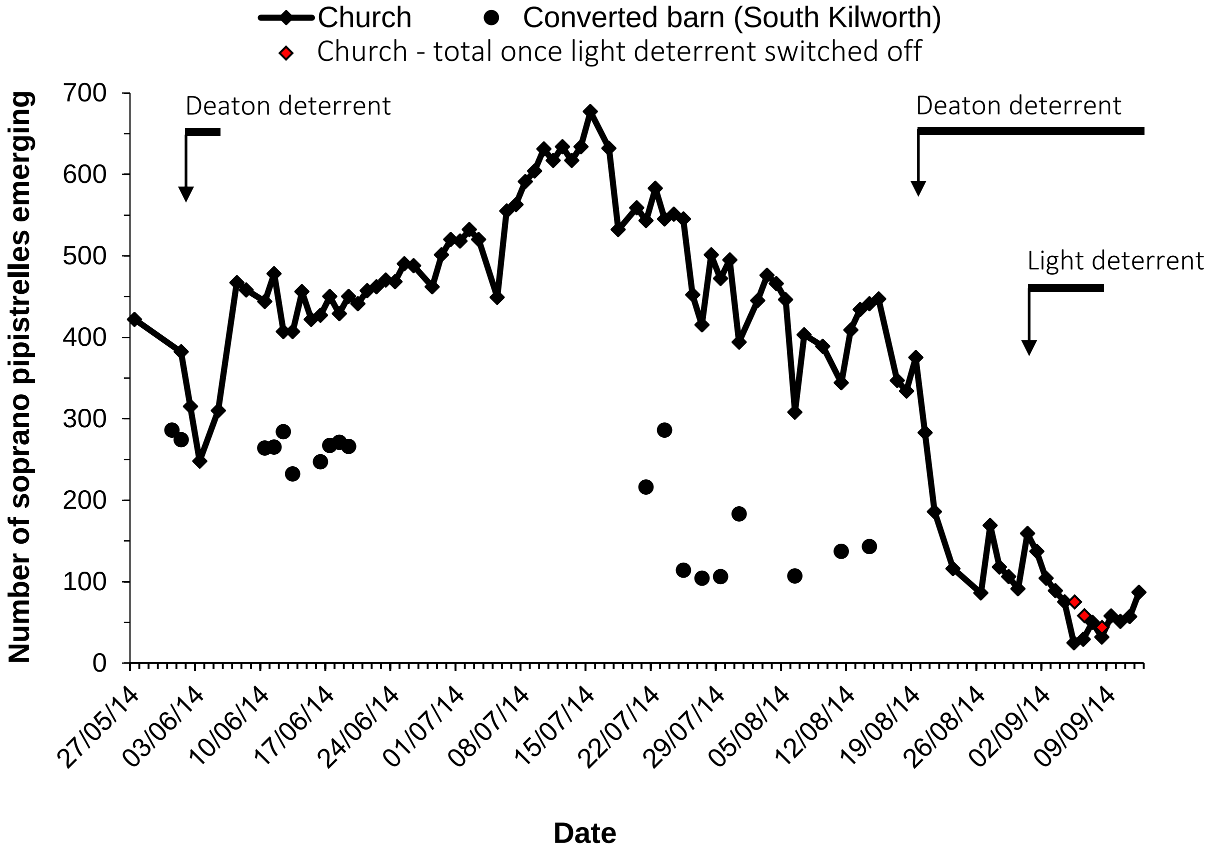

Figure 16. May-September dusk emergence counts showing numbers of soprano pipistrelles emerging from Stanford on Avon Church (around the north aisle door), along with application of Deaton and light deterrents. Emergence count data for an alternative roost in a converted barn in South Kilworth are also shown.

The light deterrent was trialled for a period of eight days. Initial set-up was with the lights positioned in the chancel doorway pointing away from the main body of the church (towards the east wall of the chancel, Figure 17, light deterrent set-up 'a'). On the first night the light deterrent was switched on after emergence until 30 minutes after sunrise, on subsequent nights it was switched on before emergence (30 minutes before sunset until 30 minutes after sunrise). Throughout the eight nights of light trials, emergence commenced at the usual time but was more protracted, on average 45 minutes longer in duration compared to the eight survey nights prior to the light trials (eight nights with lights: mean emergence duration 102 minutes (range 53-130), eight nights without lights: mean 57 minutes, range 41-65). Emergence numbers declined from 137 to 45 bats during the light trials and began to rise again once the light deterrents were removed.

Emergence duration peaked (130 minutes) when light levels were increased, with the lights positioned in the north east corner of the nave facing away from the main body of the church (towards the chancel, Figure 17, light deterrent set-up 'b'). By two hours after sunset only 25 pipistrelles had emerged. The lights were then switched off and an additional 51 pipistrelles emerged (Figure 16). The following night the original (lower intensity) light set-up was resumed, however, again by two hours after sunset only 29 bats had emerged. Switching off the lights at this point enabled an additional 29 bats to leave the church. As observed at Swanton Morley, bats trapped within the church by the light began emerging in under a minute following the lights being switched off. Despite the effect of the light on emergence behaviour, bats regularly flew into the most brightly lit area where the lights were directed – the chancel (even though this area was not being used for roosting, as an exit point, or as a route between the two), therefore the lights were not successful in creating 'no fly zones'. Light trials were discontinued due to concerns of entombing bats within the roost which with sustained use could lead to deaths.

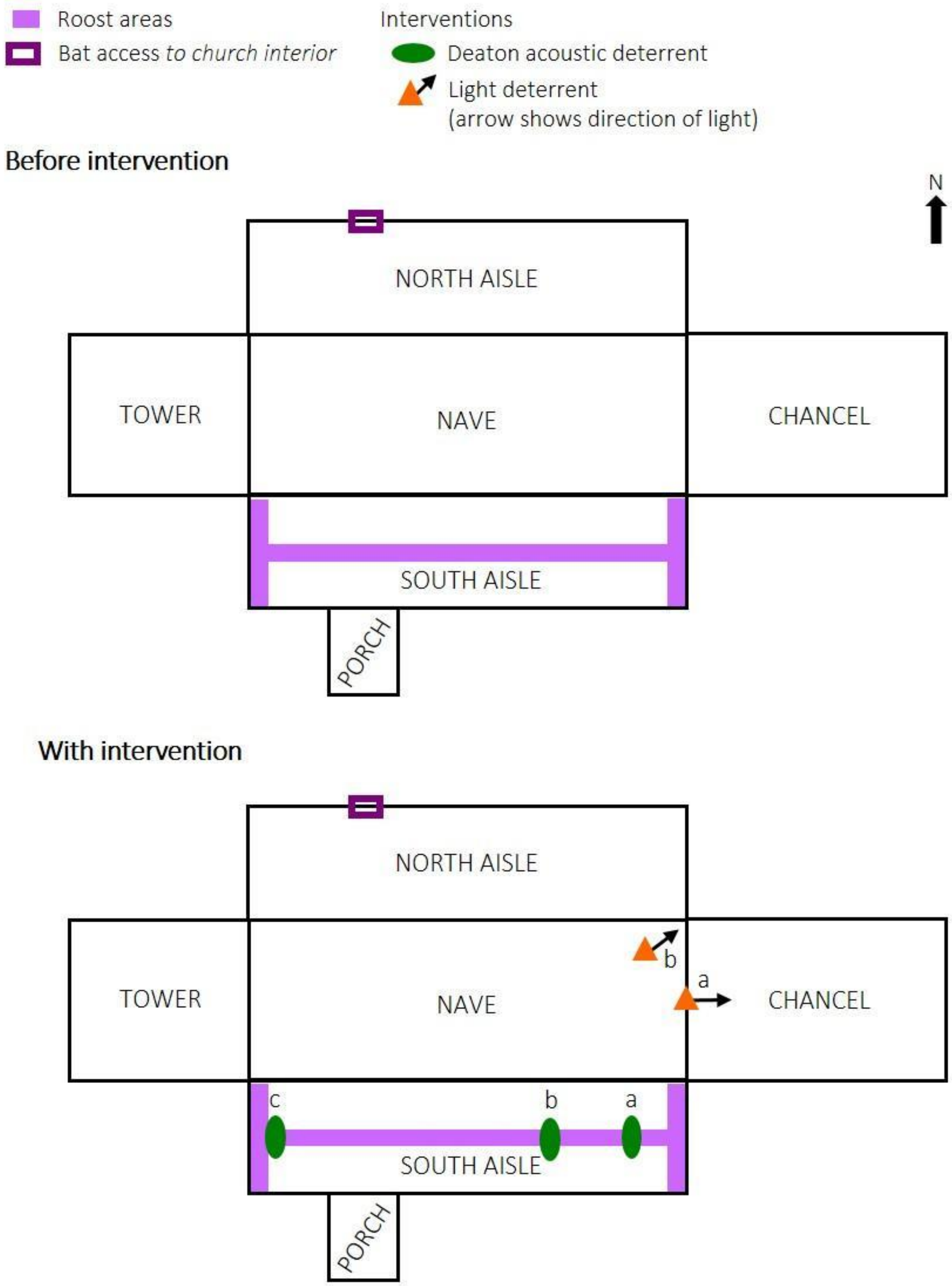

Figure 17. Simplified plan of Stanford on Avon Church (not to scale) showing main roost areas and bat access to the church interior as well as the location of acoustic and light deterrents. Letters indicate different set-ups used.

Bat boxes

The Natterer's bat boxes were checked periodically (May-September 2014); no evidence was found that the boxes had been used on the occasions when the checks were made. The soprano pipistrelle box located in the tower at Stanford on Avon was occasionally used by small numbers of bats. No evidence of use of the external boxes at Stanford on Avon was observed in the 21 days that they were up before the end of fieldwork.

Discussion

Objective 1. *To significantly reduce the impact of Natterer's bats on four target churches in Norfolk while ensuring no significant impact on the bat populations concerned.*

As found by Zeale *et al.* (2014), Natterer's bats appear to be highly dependent on the church roost and only one alternative roost away from the church (Great Hockham) was discovered during the project which could have potential to host an entire colony. Therefore complete exclusion of Natterer's bat maternity colonies from churches is likely to have a negative impact on the Favourable Conservation Status of the populations.

Holme Hale

Installation of the boxed-in areas at Holme Hale succeeded in greatly reducing the impact of the Natterer's bats on the church. Whilst emergence counts and monitoring of 10 radio-tagged bats suggested that initially an increased proportion of bats were roosting away from the church, by day 28 (post-installation of the boards) emergence count numbers were back to those recorded immediately prior to installation of the boards (despite the numbers of bats in the churches generally falling during this late season period). No effect on the timing or duration of emergence was observed.

The boards created enclosed roosting areas (north and south side, to provide different thermal conditions), with up to 46 bats using the boxed-in roosts at any one time. In addition, the installation of the boxed-in areas appeared to initiate use of the porch as a new roost (with up to 28 bats). With the majority of the colony roosting in the boxed areas and porch, the deposition of droppings and urine within the body of the church was substantially reduced. A small number of bats continued to gain access to the church interior through a gap in the north nave boxed area. These bats could not be made to stay within the north nave boxed area and were not deterred from passing through into the church interior by use of the light deterrent at the time of dawn re-entry – even when directed at the re-entry point and with the interior roost site brightly lit. The finding that bats will enter a lit roost but not exit from a lit roost (see Swanton Morley and Stanford on Avon) is supported by Zeale *et al.* (2014). Preventing the bats from accessing the church interior at the gap in the north nave boxed area would be straightforward with cherry picker access (although the bats may well find alternative entry points once this option is removed). The approach of boxing-in areas around roost entry points to retain a large roost area but prevent access into the church interior is likely to be suitable in a number of situations and could be an important tool in reducing the impact of bats in churches. However, the suitability of this approach during the maternity season and the potential impacts on productivity would need careful consideration and monitoring.

Guestwick

By the end of Phase 2, a substantial reduction in the impact of the Natterer's bats on Guestwick Church had been achieved. Application of the acoustic (Deaton and CR) deterrents moved the main roost from the most problematic area (the chancel arch) to the west end of the nave and then from there to an external position in the chancel eaves, with bats not passing into the church interior at this location. Once the main roost was in the chancel eaves, there was little evidence of bat activity within the church and few droppings were found.

The CR speakers were found to be effective when used as a set of three and placed close to the roost, showing potential for less powerful and cheaper units to be used successfully – even if additional units are required and positioning of the units is more challenging. See Appendix 2 for a preliminary assessment of 'off the shelf' rodent deterrents and their potential to be used as effective acoustic deterrents for bats.

Swanton Morley

Achieving a reduction in the impact of bats at Swanton Morley was more challenging due to the large size of the church, the considerable height of the roost locations (and therefore greater distance from the Deaton deterrents) and the many, fragmented roost sites throughout the south aisle and nave. In addition, the chancel was the only exit area used by the bats, and so there was no option to deter bats from entering the chancel (a sensitive area of the church and an unfavourable location for bat activity). However, the most heavily impacted area was the chancel arch, where large volumes of droppings accumulated on the floor in the least desirable location. Use of the Deaton deterrent successfully moved the Natterer's bats from roosting at this location (and consequently the deposition of droppings here was reduced substantially). The light deterrent was trialled with the aim of creating a 'no fly zone' to reduce dropping scatter in the north aisle and nave, but this was terminated due to the light preventing the bats from emerging. See Recommendations for a bespoke approach which could be used to reduce the impact of the Natterer's bats at this church.

Great Hockham

Natterer's bat numbers at Great Hockham were atypical during the study period, with only small numbers of bats present for much of the summer (and the maternity roost absent). Therefore the impact of the bats was much lower than usual which limited the scope for intervention at this church. As for Swanton Morley, when the bats were present they used many different roost locations spread throughout the church, but no roosts were located at or close to the preferred exit point, making effective use of acoustic deterrents difficult.

Objective 2. *Determine the impact and effectiveness of deterrents in spring/early summer.*

The Deaton acoustic deterrents were found to be highly effective in the pre-maternity period of spring/early summer for both Natterer's bats and soprano pipistrelles. The response of the radio-tagged Natterer's bats to the Deaton deterrents was very similar to that observed in previous post-maternity late summer trials (Zeale *et al.* 2014). The response of the soprano pipistrelles differed from the Natterer's bats only in that a small proportion of the tagged pipistrelles returned to the original roost on days 7 and 8 (last deterrent day and first post-deterrent day) and no tagged pipistrelles occupied the original roost on days 9 and 10 (second and third post-deterrent days).

Objective 3. *Investigate effectiveness of the management techniques at a church with a large soprano pipistrelle bat roost whilst ensuring no significant impact on the population concerned. This objective should be achieved at The Church of St Nicholas, Stanford-on-Avon.*

Despite the effectiveness of the spring acoustic deterrents at Stanford on Avon, with longer-term use in Phase 2 the soprano pipistrelles appeared to habituate to the Deaton deterrent and some continued to roost above the speakers in the south aisle, even when additional units were deployed. However numbers of pipistrelles roosting at the church declined considerably when the Deaton deterrents were applied (both in June and August-September), which is likely to have been in direct response to the deterrents (but natural fluctuations in numbers moving between roosts and late season movements away from the maternity roost could also have contributed to the patterns observed). The tendency of soprano pipistrelles to utilise a number of different roost buildings and readily adopt new roost sites (Zeale *et al.* 2014), coupled with a lack of alternatives to the south aisle for roost sites within the church, may have led to bats roosting away from the church once deterrents were impacting much of the south aisle.

Soprano pipistrelles were found to be more tolerant of the light deterrent than Natterer's bats when lights were switched on before emergence. However emergence duration was considerably more protracted, with some bats emerging much later than usual and some bats not leaving until the lights were switched off. Numbers of pipistrelles roosting at the church also fell. Therefore there is a considerable risk of detrimental impacts on bats from sustained use of light deterrents, with behaviour altered and bats trapped within the roost there is potential for the death of many bats through entombment.

Neither of the deterrent techniques is likely to be suitable on its own for soprano pipistrelles in the longer term. However, it should be noted that this is based on a single test site (Stanford on Avon) only. The promising initial results of the spring deterrent trials however suggest that acoustic deterrents may be effective in the short-term and could be useful for temporarily moving a roost away from a vulnerable area of the church to allow subsequent roost-blocking to be undertaken. Failure of the acoustic deterrents to move bats from the south aisle may also be strongly related to a lack of suitable alternative roost locations within the church. Light deterrents would not be recommended for most situations and if employed would need very close and careful monitoring (see Appendix 3 for a guidance document on the use of deterrents). Churches with problematic soprano pipistrelle roosts are likely to need to use additional bespoke measures (see recommendations for Stanford on Avon below) to achieve a reduction in impact of the bats whilst ensuring no negative effects on the bats themselves.

Unlike Natterer's bats in the Norfolk churches, the soprano pipistrelles at Stanford on Avon made use of a major alternative roost away from the church. However, with peak counts at the barn roost of 286 soprano pipistrelles (along with 146 common pipistrelles), this modest-sized residential building may not be able to support additional bats and any influx of pipistrelles from the church roost could risk potential negative impacts on the building and prove problematic for the residents.

Objective 4. *Refine and optimise the operation of techniques and equipment and to produce a toolkit for the effective and safe management of bats in a church context.*

During Phase 2 the operation of deterrents, along with exploration of additional 'bespoke' measures, was refined and optimised to achieve the safest and most effective outcomes. A guidance document, containing a summary of the research findings, deterrent specifications, set-up and operation can be found in Appendix 3. The guidance document, along with a licensing framework and policy information being developed by Natural England and Defra, will form the toolkit for effective and safe management of bats in churches.

Objective 5. *Communicate the aims, progress and results of the trial to all stakeholders.*

This objective is ongoing, with aims, progress and results communicated as the project has progressed (by the University of Bristol – directly with the study churches, and by the Bat Conservation Trust – with other stakeholders and bat workers) and will be completed when the project findings are finalised.

Recommendations

Recommendations and guidance on the use of deterrents and bespoke 'boxing-in' measures to reduce the impacts of bats in churches are given in Appendix 3. A basic assessment of 'off the shelf' rodent deterrent units (see Appendix 2) would suggest there may be some readily available and affordable units with potential for use as bat acoustic deterrents in churches, although these will require more detailed testing and trials *in situ* before they can be recommended for use. Deterrents were only used prior to the onset of parturition and after pups were volant. We do not know what the effects of the deterrents would be during parturition and before pups are volant, therefore given the lack of evidence deterrents should not be used during this period (see Appendix 3).

No evidence of use of the Natterer's bat boxes was found when checks were made and alternative designs should be considered. Following discussions on design and requirements, Peter Geary and Patty Briggs, experienced and innovative bat box makers, have very generously built three large heated Natterer's bat boxes and donated them for use in Norfolk churches - these should be installed and monitored. The external boxes at Stanford on Avon should be trialled for a longer time period.

Holme Hale

The bespoke boxing-in measures have potential to greatly reduce the impacts of bats on the church whilst retaining a roost site at the building. However, before committing to major permanent measures, a further trial period with temporary boxing-in measures installed prior to the maternity period and retained for the whole season (April-October) would be advisable. This would allow the effects of this approach during the maternity period to be assessed and the location of any additional access points identified. This would also enable an assessment as to whether the two short sections boxed-in for the temporary trial (north and south side, each approximately 5m in length) should be permanently boxed (preferable as cheaper and easier to maintain/clean out droppings) or whether the bats are likely to use alternative entry points along the nave. In which case, the whole length of the eaves' void on both sides of the nave would need to be boxed-in to increase the likelihood of successfully preventing the bats from entering the church interior. This would also be beneficial as larger roosting areas would be created, however the cost of implementation and labour involved in maintaining and clearing out the boxed-in areas would be considerably higher. The addition of roost features fixed on to the boards (on the eaves interior side) could increase roosting options and suitability as a maternity site, as the mortise-joints used are small and may not be suitable for a nursery roost. However such features must not obstruct or restrict flight areas within the boxes.

In late summer the church was used as a swarming site by pipistrelles. Few pipistrelles were roosting in the church interior, but would enter the church from around the time that the Natterer's bats had completed emergence and swarm in the church for a period of several hours before exiting again. It is likely that implementation of the boxed-in areas would not prevent this from happening as the pipistrelles appear to have a greater range of access points available to them, but this would need to be considered if implementing the boxed-in areas long-term. Minimal impacts on the church from the pipistrelles were observed.

Guestwick

Measures aimed at encouraging the bats to only use the exterior chancel eaves roost could substantially reduce dropping accumulation within the church. As for Holme Hale, the suitability of the exterior chancel roost for the maternity period would need to be assessed through trialling this approach for a whole season (April-October). The acoustic deterrents can be used to deter the bats from the main roost locations inside the church (the chancel arch and the west end of the nave) and these locations can subsequently be blocked, encouraging the bats to roost in the exterior chancel eaves (as achieved in Phase 2). If the acoustic deterrents alone are not sufficient to encourage the bats to roost solely in the chancel eaves, exterior access points into the main body of the church would need to be blocked (which may prove challenging). If successful this would allow retention of the roost at the church (in the exterior chancel eaves) but prevent bats from accessing the church interior.

Swanton Morley

Due to the complexity of the situation at Swanton Morley, solution options are quite limited. However, a strategy worth investigating would be to temporarily block access into the church interior (through gaps where the plaster has fallen away in front of the south chancel eaves) after emergence during the early (pre-maternity) season and see if the bats adopt the chancel eaves' void as a roost site on re-entry. This is similar to the boxing-in approach at Holme Hale, although without any prior confirmation of bats utilising this area for roosting and therefore with more uncertain outcomes and risks. Full inspection to assess the suitability of the eaves' void as a roost site was difficult due to the height and limited endoscope access. As this approach may result in the bats leaving the church completely, a sample of the colony should be radio-tagged prior to the trial so that the location of roosts away from the church can be determined. The bats may find alternative access points into the church (the north chancel gaps in the plaster should also be temporarily blocked as this is a little used access point), however due to the structure of the church alternative access points are likely to be limited. Temporary blocking of the gaps in the plaster should include a one-way exclusion device allowing any bats that may have remained within the church after emergence to pass through into the desired eaves' void roost area and exit (to avoid trapping any bats inside the main body of the church).

Great Hockham

If the full colony returns to Great Hockham an assessment can then be made as to the best strategy for this church. One potential solution could be to encourage the bats to roost in close proximity to the main exit point at the east end of the north aisle (away from the vulnerable organ and ancient wall paintings). However, with low numbers present during the study period and bats roosting in multiple and frequently changing locations throughout the church, it was not possible to attempt this approach during the project. Bats were found to roost at the east end of the north aisle by Zeale *et al.* (2014), but not during this project, which may have been due to flood damage rendering the area unsuitable for roosting.

Stanford on Avon

As for Holme Hale, with a colony of this size (peaking at 677) roosting freely in the church interior, it is difficult to imagine a satisfactory solution which would achieve an acceptable reduction in impact whilst the bats continue to use the church interior. It was not possible to move the bats from the south aisle with the acoustic deterrents and there is no obvious preferable roost site within the church. As the soprano pipistrelles have a major alternative roost away from the church and have been found to be more adaptable and able to readily establish new roosts (Zeale *et al.* 2014), a boxing-in approach could also be trialled here.

This would involve the construction of a very large heated bat box fixed to the back of the north aisle door (where the bats enter, the door is not used by people or needed for access). The box would need to be large enough to support the whole colony. Heating would be advisable due to the cooler conditions experienced on the north side of the building. The box should be erected after emergence. At dawn the bats would be able to re-enter via their usual route above the north aisle door, but instead of entering the church interior, they would be contained within the roosting box. A one-way exclusion device would need to be fitted to the side of the box facing the church interior, to allow any bats which may not have emerged from the church to pass into the box and exit at the usual point.

A large heated box should also be placed on the exterior wall, adjacent to the north aisle door, to provide an additional roost option. Its proximity to the church access point should reduce the time taken for the box to be discovered. Radio-tracking is strongly recommended prior to installation of the internal box, as the bats are unlikely to use the boxes, at least in the short term, and may form a new roost elsewhere. Therefore radio-tracking is likely to be the only way to gain a good understanding of the outcomes and assess success (bats roost in the boxes or form a new, suitable maternity roost elsewhere) or failure (bats find alternative entry points into the church and continue to roost in the interior or bats do not use the boxes and fail to form a new colony roost elsewhere).

It is quite likely that the bats may find alternative entry points into the church (only the chancel door has signs of occasional access use and gaps around the edges could be easily blocked – along with the main south aisle door). It should also be noted that there is a brown long-eared bat colony in the nave roof void (separated from the church interior and therefore unlikely to be impacted by these measures).

Considering the landscape as a whole, the church roost is positioned south of a large reservoir (to which it is linked by the River Avon), which is highly likely to be a key foraging area for the church bats and a major factor in their presence at the church in large numbers. Similarly, the barn roost is located north of the reservoir and also linked to it by a river (an ideal commuting route). In the vicinity of the reservoir roosting options appear somewhat limited with few large, mature trees and the nearest suitable sites for large maternity roosts may well be the church and the barn. Therefore consideration should be given to the construction of an artificial roost on the likely commuting route along the river between the church and the reservoir (this would need to be confirmed with surveys and/or radio-tracking and the ideal location for the roost determined accordingly). Provision of a well-designed and carefully sited artificial roost in close proximity to the reservoir (and along known commuting routes, therefore increasing the likelihood of discovery) could prove to be a desirable alternative roost in an area where options may be limited. If the roost was adopted (which could take a number of years) it could help to alleviate the problems experienced at the church due to the large numbers of bats.

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Appendices

Appendix 1: Implementing the boxing-in trial at Holme Hale
Appendix 2: Preliminary assessment of ultrasonic rodent deterrents and their potential as bat deterrents
Appendix 3: Draft guidance on techniques to reduce the impacts of bats in churches

Appendix 1

Implementing the boxing-in trial at Holme Hale Church

Permissions

The boxing-in trial measures were agreed after detailed discussions with the PCC and the church architect. As the measures were temporary and required no permanent fixings, Faculty Permission was not required.

Access

The eaves were accessed using a Hinowa Goldlift 14m Access Platform hired from Ben Burgess. A suitably experienced person was hired to operate the Access Platform.

Materials and installation

Droppings were removed from the floors of the eaves' voids which were then covered with lining paper to protect the wall tops and allow monitoring of the volume of droppings accumulating. The eaves' voids (see Figure 1) were temporarily boxed-in using hardboard, cut to fit and secured in place with Duct tape. Sections of the hardboard interior side were covered with thick greenhouse shading mesh (3mm mesh size) to aid grip, allowing bats to climb up the boards to the roost areas. Gaps were temporarily filled with cloth and sponges. The materials and methods used were suitable for temporary measures only. Long-term installation would require guidance from the church architect, Faculty Permission and appropriate materials (in keeping with the appearance and materials used in the church and sufficiently robust for long-term use) with permanent secure fixings.

The north aisle eaves were subsequently temporarily blocked with sponges to prevent access by alternative entry points. A one-way exclusion device (see Figure 2 and the Bat Workers' Manual[1]) was fitted to allow any bats remaining inside the church to exit at this point, but not re-enter. The one-way exclusion device was constructed from a rigid plastic guttering/downpipe bend, attached with Duct tape to the exit/entry point on the exterior of the church. The lower end was encircled by a plastic rubble sack, creating a collapsible 'shoot' (allowing bats to exit but preventing them from gaining purchase on the slippery material and/or finding their way through to climb up and re-enter).

[1] Mitchell-Jones, A.J. and McLeish, A.P. (2004) Bat Workers' Manual 3rd Edition. Joint Nature Conservation Committee

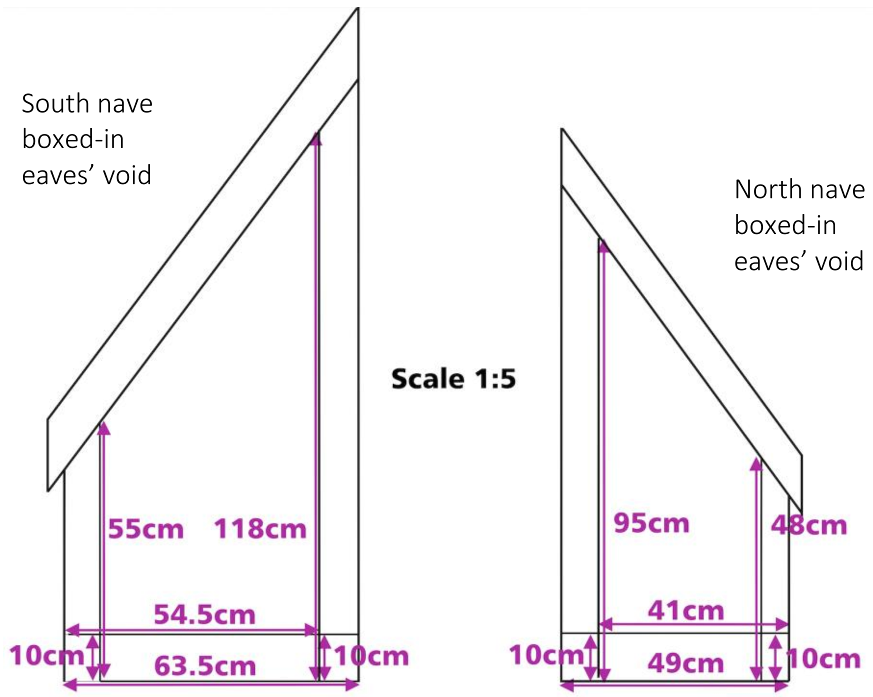


Figure 1. Cross-section of the south and north nave boxed-in eaves' voids. The length of each boxed-in area was approximately 5m. Diagram provided by Philip Parker Associates.

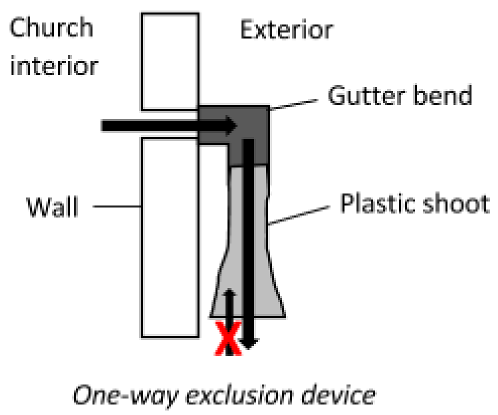


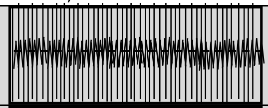
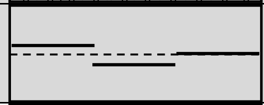
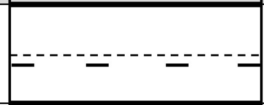
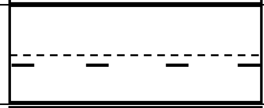
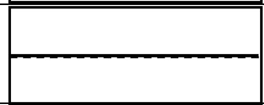
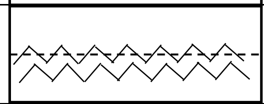
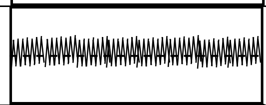
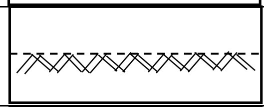
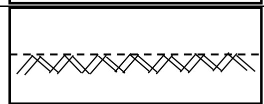
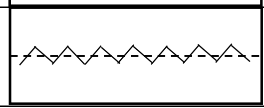
Figure 2. Sketch of a one-way exclusion device used on the north aisle access point at Holme Hale Church.

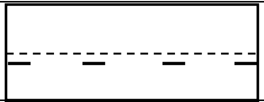
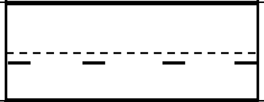
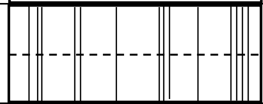
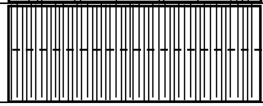
Appendix 2

Preliminary assessment of ultrasonic rodent deterrents and their potential as bat deterrents

Twelve cheap and readily available acoustic rodent deterrents were given a basic assessment to determine their potential for use in managing the impacts of bats in churches. Spectrograms were produced for each rodent deterrent unit using a Wildlife Acoustics Song Meter 3 bat detector, placed 1.5 metres from the unit. Deterrents were also monitored through a Batbox Duet heterodyne detector to provide a subjective impression of sound intensity. Details of the units are given in Table 1, along with the two acoustic deterrents units used in the Defra and English Heritage funded projects – Deaton and Concept Research (CR). Key attributes in assessing potential for these units to be effective bat acoustic deterrents were the spectrograms (shown here as simplified schematics), volume and cost. Note that the CR device had very limited running time from batteries, and mains power was necessary for long-term use. Six units were thought to have medium-high potential (Table 1). Note three of these units also feature an 'electromagnetic deterrent' element. The effect of this on bats in unknown and would need careful consideration before trialling in a church. Those units considered most likely to be safe and effective should undergo testing and *in situ* trials. **Use of deterrents in the vicinity of a bat roost is only permitted with advice and is illegal without a licence.**

Table 1. Preliminary assessment of consumer ultrasonic rodent deterrents.

Unit	Power source	Additional ‘deterrent features’: electromagnetic (EM) / ionic (IN) / infrared (IF)	Volume	Spectrogram schematic (x=time, y=frequency, dotted line indicates 50kHz)	Cost per unit (Dec 2014)	Potential as bat deterrent
Deaton	Mains	No	Loud		n/a	n/a
Concept Research	x1 9v battery, mains	No	Medium		n/a	n/a
A	x1 9v battery	No	Medium		£17.50	No
B	Mains	Yes – EM + IN	Quiet		£39.97	No
C	Mains	EM	Medium		£29.45	No
D	Mains	No	Medium		£19.99	**Medium**
E	Mains	Yes - EM	Medium		£26.99	**Medium/high**
F	Mains	Yes - EM	Medium		£27.00	**Medium**
G	Mains	Yes - EM	Medium		£15.99	**Medium**
H	Mains	Yes – EM, IF	Medium		£17.49	Low

I	Mains	No	Medium		£64.90	No
J	Mains	Yes – EM, IN	Medium		£13.95	No
K	Mains	No	Medium/loud		£19.99	**High**
L	Mains	No	Loud		£66.49	**High**

Appendix 3

Draft guidance on techniques to reduce the impacts of bats in churches

Introduction

- This document provides guidance to bat workers and ecological consultants on the use of ultrasonic acoustic deterrents and bespoke (e.g. 'boxing-in') approaches to reduce the impacts of bats in churches whilst safeguarding bat populations.
- Here we describe techniques found to be effective during research and pilot projects on Natterer's bats and soprano pipistrelles (Zeale *et al*. 2014 and Packman *et al.* 2015).
- The aim of deterrence is to encourage bats to move away from locations inside churches where they cause particular problems for church users, to areas where they can be tolerated, thereby alleviating conflict resulting from deposition of droppings and urine.
- Deterrents are not intended to be used for excluding bats from churches.
- The long term impact of deterrents/bespoke measures on bat populations needs to be carefully monitored.

Licensing

- In England, bat workers/ecological consultants intending to use deterrents to manage the impact of bats in churches will require a licence from Natural England that specifically permits these methods (Bats in Churches Class Licence).
- Experienced individuals will be registered to use this class licence following training.
- As part of the licence a bat management plan will need to be produced which details the work that will be undertaken.
- This guidance has been produced for use in England. In other parts of the UK advice and the appropriate licences should be sought from the relevant Statutory Nature Conservation Organisation.

Planning mitigation work

It is important that any such work is undertaken in close consultation with, and with consent from, the Churchwardens and/or Parochial Church Council (PCC) (or equivalent for non-Church of England buildings). Any work which may involve fixtures/fittings/construction elements will require advice from the Diocesan Advisory Committee (DAC) to obtain Faculty Permission and may need guidance from English Heritage. It may also be necessary to consult the church architect for further guidance/advice.

Table 1 outlines the steps involved in implementing measures to reduce the impacts of bats on a church. In the first instance, it will be important to liaise with Churchwardens/PCCs to gather information on the history of bat activity in the church and to understand the main issues being faced.

Common issues include:

- accumulation of droppings, creating a cleaning burden
- staining and damage from urine: walls, pews, floors, organ pipes, stonework, monuments, wall paintings and rood screens
- a strong and unpleasant smell
- disruption to services from bats flying inside the church (and audible vocalisations)
- grounded bats (particularly pups)

It will then be essential to obtain a thorough (and up-to-date) understanding of the numbers and species of bats present, roost locations used (usually multiple roosts within the church) and all entry and exit points (these can be different) utilised by the bats, including seasonal variation. It is anticipated that this work will require a greater number of surveys, surveys of a more in-depth nature, and surveys conducted over a longer period of time, compared to standard surveys used for commercial bat mitigation work (see Hundt 2012). The level of survey effort required will be church-specific. For cases where a single bat species is found to be responsible for the majority of the problematic impacts experienced, consideration of the effects of any proposed mitigation measures must be given to other species that may be present in smaller numbers (or in a location or type of use that does not impact the church).

Table 1. Outline of the process of implementing deterrent/bespoke measures in churches

	Steps	Action
Pre-mitigation baseline information	*History of bat occupation in the church* - how long has the roost been present (if known)? - when did the roost start to become problematic? - where do the bats roost/droppings accumulate? - what are the problems associated with the presence of the roost? - which areas/features are most affected? - which areas/features are most in need of protection/most vulnerable (e.g. monuments, wall paintings, rood screens)? - where would the preferred location for the roost be (area least likely to be problematic/less sensitive/vulnerable)?	Discuss in detail with Churchwardens/PCC to obtain full history and gauge extent of problem and attitudes. Record the information collected and map the described features and information on a sketched plan of the church.
	Records - are there any records of bat species and numbers for the church? - are there any other known roosts in the vicinity of the church (which may be used by the church bats as an alternative/linked roost)?	Check local biodiversity records centre/NBN Gateway. Contact local bat group. Check if there have been any previous Volunteer Bat Roost Visitor inspections/NE Advice letters issued.
	Survey information - bat species present (including non-target species which may be affected by mitigation measures) - numbers of each species present	Internal and external visual inspections. Dusk and dawn surveys (with surveyors

	- types of roosts of each species present - all roost locations (usually multiple roost sites used within the church) - all entry and exit points, both internal and external, used by the bats (may be different between species) - seasonal variation: preferred roost locations often change through the season according to conditions and needs, preferred entry/exit points may also vary, count data can fluctuate considerably day-to-day and through the season (therefore multiple emergence counts are required)	positioned internally as well as externally), conducted over the course of the active season (i.e. typically May-August) as advised by Hundt 2012.
Planning	*Planning mitigation measures* - discuss and agree on aims, mitigation approach/measures to be implemented, desired outcomes etc. with Churchwardens/PCC - create a bat management plan (including what to do if measures are unsuccessful in reducing impact on the church or are thought to be causing negative impacts on the local bat population), a requirement for using the Bats in Churches Class Licence (see Natural England's Bats in Churches Class Licence for more details) - obtain any additional bat licence if required (if methods not covered by the Bats in Churches Class Licence are to be used) - obtain Faculty Permission if required (for fixings/construction work etc.)	Discuss with Churchwardens/PCC, DAC & English Heritage (if Faculty Permission required), Natural England (if additional licence(s) required).
Mitigation implementation	*Implement mitigation measures (Phase 1)* - implement measures as described in the bat management plan - closely monitor effects of deterrents/bespoke measures: dusk/dawn surveys (is the timing of emergence or numbers of bats using the building affected?), roost locations (have these changed?), internal observations (is bat behaviour/activity affected?) - if measures are unsuccessful in reducing the impact on the church or there is concern that measures are having a negative impact on the bats (more than short-term disruption), appropriate action (as described in the bat management contingency plan) must be taken	Implement and monitor intensively (i.e. daily when first implemented, less regularly once bat response has stabilised and is satisfactory).
	Long-term mitigation measures (Phase 2) - maintain long-term/permanent measures - monitor - report (as per conditions of licence) - feedback details of background, measures implemented, outcomes, survey and monitoring information to assist others and further improve knowledge of successful techniques - if measures fail to reduce the impact on the church longer-term or the local bat population is thought to be negatively impacted longer-term, appropriate action must be taken (following the contingency plan as described in the bat management plan)	Lower intensity monitoring for a minimum of 4 years (3 surveys per active season advised)

With good baseline information, suitable mitigation (reduction of the impact of the bats on the church whilst ensuring no detrimental long-term impact on the local bat population) can be planned in consultation with Churchwardens/PCCs and with the required permissions and licences (see Table 1).

Implementing mitigation

The mitigation measures are likely to involve two phases: first, an ‘active’ or temporary phase, where measures are initiated and the aim is to actively move bats away from problematic areas (Phase 1). If this is successful then the mitigation can enter a long-term maintenance phase, where bats are no longer being actively deterred from a given location, having already moved away to the desired roost site, and the mitigation is aimed at maintaining this effect (Phase 2). For example, having moved bats away from a sensitive roost location(s), the roost site(s) may then be blocked (once it is certain no bats remain there and with a temporary one-way exclusion device fitted). This can remove the need for long-term application of deterrents. If the layout of the original roost is such that it cannot be blocked effectively, small deterrent units can be wired-in and fixed close to the roost for long-term deterrence.

Phase 1 should only be undertaken **outside of the period when females are heavily pregnant, giving birth and have dependant pups** (not yet volant) i.e. typically outside late May-late July (depending on the species and conditions in that season). If Phase 1 active mitigation is successfully completed and Phase 2 (stable, low-impact maintenance) has been reached before this period, an assessment will need to be made as to the safety and likely impact on the colony of any Phase 2 measures in place (supported by careful monitoring). This will determine if it is safe to continue with the Phase 2 maintenance measures through the sensitive maternity period. It should be noted that while acoustic deterrents are considered to be a safe technique when implemented appropriately, the ultrasound could interfere with mother-pup communication and therefore its **use during the maternity period must be avoided**. In addition, Phase 1 should not be implemented during the hibernation period.

Monitoring requirements will be greater than that for standard bat mitigation work. During Phase 1, close monitoring will be required. During Phase 2, monitoring is required to assess long-term effects and success/failure of the approach and to make any necessary alterations to the mitigation measures. It may take a number of years before the success/failure of the measures can be fully assessed. Experience and outcomes should be shared between users of the Bats in Churches Class Licence to enable others and promote continuous improvements in techniques and methods.

Acoustic deterrents

Acoustic deterrents have been found to be effective for relocating Natterer’s bats from one roosting area to another within a church (e.g. from above a sensitive area such as an ancient monument to a less sensitive area of the church) during spring and after the lactation period has ended. Acoustic deterrents can also prevent the colony from returning to that roost location longer-term (Zeale *et al.* 2014 and Packman *et al.* 2015). Moreover, they do not affect the foraging behaviour, ranging and habitat selection of Natterer's bats (Zeale *et al.* 2015). However, current evidence suggests that acoustic deterrence is less effective longer-term for soprano pipistrelles, which appear to eventually habituate to ultrasound and return to roost above the deterrent (but could still be effective for initial moving of the roost location to be followed by blocking of the original roost site). The 'tolerance' of bats to acoustic deterrents is likely to be partly determined by the availability and suitability (which can change with season) of alternative roost sites within (and outside of) the building, i.e. if there is only one suitable roost location within the church and this is targeted with the acoustic deterrent, bats may continue to roost at that location (or move only a short distance away); however, if other suitable locations are available, the bats may readily relocate. Acoustic deterrents can be highly directional and have limited range. Bats will fly through the affected zone and have not been found to be trapped if still inside the roost area being targeted.

Specifications

The Deaton units (Arnett *et al.* 2013) used in the research projects are expensive and not commercially available. However some consumer rodent ultrasonic deterrents show promise as affordable alternatives (£15-70 per unit) and are being tested further (see Packman *et al.* 2015). These smaller and less powerful units will need to be positioned close to the target roost site and more than one unit per roost site may be required. **Use of such deterrents would be illegal without a licence.**

When to use

Ideal for situations where bats have more than one roost location within the church (common) and the aim is to move the bats away from a specific roost site(s) in a sensitive area of the church. By applying additional sets of deterrents to other roost locations (followed by blocking), the bats can gradually be moved to the desired roost. Acoustic deterrents can work well in situations where this is one or a small number of problematic roost locations and where most of the impacts are associated with droppings and urine accumulation directly beneath the roost site. There needs to be a suitable roost site within the church where droppings/urine falling from the roost can be managed and no vulnerable items are positioned below.

When not to use

May have limited use in complex situations where the church is large and the roost fragmented into many smaller roosts at multiple sensitive locations throughout the church (as the area affected by the deterrent is limited and many deterrent sets would be required). Cheaper/smaller/less powerful acoustic deterrent units need to be placed close to the roost (ground level is likely to be insufficient unless using a powerful unit and the roof is low), so consideration needs to be given to how to access high areas and how the deterrents will be fixed (temporarily) in close proximity to the roost. If there is no roost site where impacts can be limited, then a 'boxing-in' approach may be more suitable (see below). Acoustic deterrents are also unlikely to be an effective tool where the majority of impacts are associated with general scatter of droppings/urine from bats in flight (as opposed to from the roost site - see the 'boxing-in' option as an alternative).

Set-up

Position acoustic deterrents facing directly at the roost. Avoid 'blocking' the sound output by structural features. Effective distance from the roost will depend on unit type (the smaller units used in the research were placed c.1.5-2m below the roost in a set of three). The large/powerful (Deaton) units were effective at table height (up to 13 m from the roost).

Deterrents should be connected to a timer switch, to be activated from 30 minutes before dusk until 30 minutes after dawn (activate after emergence on the first night of use). It is not necessary to have the deterrents on during the day; many are audible to humans and therefore would be obtrusive. If no sound audible to humans is produced, continued use of the deterrents during daytime might increase their effectiveness however as bats are frequently absent from roosts during the night. Acoustic deterrents can take at least several nights (sometimes longer) to effectively move all the bats from the roost.

Bespoke (e.g. 'boxing-in') measures

In churches with large maternity colonies roosting freely in the church interior and where limited alternative roost locations exist, deterrent use alone may be insufficient to reduce the impact of the bats on the church. Therefore 'bespoke' measures may be needed in addition to, or instead of, deterrent use.

A bespoke approach was trialled during the research project at a site with a large maternity colony of Natterer's bats. 'Boxing-in' of 5m-long sections of the eaves' voids around entry points (on both the north and south sides of the nave) was trialled (see Packman et al. 2015 for further details and photos). This retained two large roosting areas (with differing aspects and hence probably different thermal properties) and, importantly, the original entry points used by the bats, but prevented access into the rest of the church. The 'boxed-in' areas were sufficiently large to allow bats to fly inside them. 'Boxing-in' also required blocking of other entry points into the church (other than those providing access into the boxed areas) and the installation of a one-way exclusion device to allow any bats remaining inside the church to exit and only re-enter into the boxed-in areas. This approach was successful in providing roosting areas whilst significantly reducing the impact of the bats on the church. However further testing is needed as this trial came towards the end of the main period of summer roost use and has not been trialled for the maternity period, when roost requirements are likely to be different.

When to use

When a large and problematic roost is present, with no alternative unproblematic roost locations. Also when droppings/urine deposited in flight around the church interior is a major problem (as opposed to the primary issue being accumulation of droppings/urine directly beneath the roost site). This approach is only suitable when access points are limited and there is suitable roosting space behind the access points which can be boxed-in. The roosting areas will need to be of sufficient size to accommodate the whole colony and should offer a range of conditions and roost features. If the species concerned needs flight space within the roost area, this must also be factored into the space requirements. A season-long temporary trial is strongly recommended before deciding to implement these measures long-term (which would require permanent construction features and therefore Faculty Permission would be needed). Consideration as to how the boxed-in areas will be maintained long-term, such as annual removal of droppings, is needed.

When not to use

When many areas are used by the bats for access into the church and it is problematic to block or unlikely to be feasible to address all entry points. Access points must be restricted - either to be encompassed within boxed areas or blocked (those outside of the boxed areas). Boxed-in roosting areas are likely to prove most successful when they incorporate features already present and which are already being used for roosting by the bats. In some circumstances it may be possible to create an artificial roost area for this purpose if no original roost features exist. These should be connected to established access points, but success is less likely and will almost certainly take a longer time to achieve. As bespoke boxing-in methods require construction work which may affect the internal appearance of the building (as well as increasing the cost of the work), it should only be undertaken in cases where damage and/or disruption is considered severe. Aesthetics and design will need careful discussion and planning with the Churchwardens/PCC and church architect. Therefore this approach should only be considered when options for acoustic deterrent use have been explored and the likelihood of achieving a reduction in impact by deterrent use alone is unlikely.

Artificial lighting

General equipment items list:

- High-power torch for internal inspection
- Head torch
- Endoscope
- Bat detectors (heterodyne and passive recorders)
- Infrared video camera with infrared floodlights or nightscope (can be useful, especially for species which emerge late e.g. Natterer's bats)
- Tally counters
- Dust sheets/lining paper (to monitor dropping accumulation and/or protect sensitive features which may inadvertently experience a temporary increase in dropping/urine deposition whilst mitigation measures are being implemented)
- Dust pan and brush
- Sample pots (for recording amount of dropping deposition or samples for DNA species identification e.g. for some *Myotis*)
- Dust masks
- Bat handling gloves
- Hand net
- Extension ladders
- Deterrents with extension cables and timer switches
- Hazard tape (to secure over any loose cables on the floor or cordon off areas as required)
- Sponges (for temporary blocking)
- One-way exclusion devices (e.g. made from drain pipe bend and rubble sack – see the Bat Worker's Manual, Mitchell-Jones & McLeish 2004)

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