Brown long-eared bat roost monitoring scheme for Republic of Ireland: synthesis report 2007-2010

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Brown long-eared bat roost monitoring scheme for the Republic of Ireland: synthesis report 2007-2010

Tina Aughney[1], Steve Langton[2] and Niamh Roche[1]

1. www.batconservationireland.org

2. stats@slangton.co.uk

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The NPWS Project Officer for this report was: Dr Ferdia Marnell; Ferdia.marnell@ahg.gov.ie

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Executive Summary

Monitoring the brown long-eared bat is problematic. This species has very quiet echolocation calls, which means that schemes reliant on bat detectors will not yield sufficient data to produce population trends.

This monitoring scheme takes advantage of the species' roost fidelity and involves counts of individual bats at summer roosts. The exact methodology that is used is adapted to the conditions at each specific site, such as whether there are multiple exit points and whether it is possible to access the internal roof void.

80 volunteers participated in this monitoring scheme from 2007-2010. Of the 252 surveys completed, 143 (57%) were completed with volunteer assistance. In total, 57 roosts were surveyed with an additional 61 buildings assessed but not deemed suitable for monitoring.

Using the highest counts for each roost monitored in 2010, the total number of brown long-eared bats counted was 1,481 individuals. Power analysis indicates that the current target of 30-50 roosts should provide robust data to determine red or amber alert declines, or 50% increases in brown-long eared bat populations.

Habitat analysis was carried out on a sub-sample of monitored sites. Roosts located in rural areas had significantly higher average counts than roosts located at an urban edge. In addition, there was a significant positive correlation between bat numbers and a 'woodland edge' component; higher numbers were associated with increased commuting distances, but higher woodland cover within 2.5km of the roosts. The implications of this are discussed.

Recommendations are made for the continuation and expansion of the monitoring scheme. The inclusion of the remaining pNHAs listed for brown long-eared bat is identified as a priority.

Greater volunteer involvement, including the further engagement of roost owners themselves, should be investigated to improve the cost-effectiveness of the programme.

Further research on commuting routes and foraging habitat would aid the conservation of this species.

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Introduction

The Brown Long-eared Bat Roost Monitoring Scheme is a project funded by the National Parks and Wildlife Service (NPWS) of the Department of Arts, Heritage and Gaeltacht, Republic of Ireland. This scheme aims to be the primary tool for monitoring brown long-eared bats in the Republic of Ireland. This monitoring protocol was devised and piloted by Bat Conservation Ireland (BCIreland) in 2007 and has been managed by BCIreland since then.

This report presents a synthesis of results for the first four years (2007-2010) of brown long-eared bat (*Plecotus auritus*) monitoring in the Republic of Ireland and follows earlier annual reports produced by BCIreland.

Why Monitor Brown Long-eared Bats?

Bats constitute a large proportion of the mammalian biodiversity in Ireland. Nine species of bat are known to be resident on the island of Ireland and form almost one third of Ireland's land mammal fauna. Bats are widely distributed throughout the range of habitat types in the Irish landscape. Due to their reliance on insect populations, specialist feeding behaviour and habitat requirements, they are considered to be valuable environmental indicators of the wider countryside (Walsh *et al*., 2001).

Irish bats, including the brown long-eared bat, are protected under Irish and EU legislation. Under the Wildlife Act (1976) and Wildlife (Amendment) Act 2000, it is an offence to intentionally harm a bat or disturb its resting place.

The EU Directive (92/43/EEC) on the Conservation of Natural and Semi-natural Habitats and of Wild Flora and Fauna (The Habitats Directive) lists all Irish bat species, including the brown long-eared bat, in Annex IV while the lesser horseshoe bat (*Rhinolophus hipposideros*) is also listed in Annex II. Member states must maintain or restore 'Favourable Conservation Status' of species listed in Annex II, IV and V. Favourable conservation status is defined as 'the sum of the influences acting on the species concerned that may affect long-term distribution and abundance'. Article 11 of the Directive requires 'Member States to undertake surveillance of the conservation status of all bat species.

Ireland is also a signatory to a number of conservation agreements pertaining to bats including the Bern and Bonn Conventions. Under the Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals, 1979), Ireland is a signatory of the European Bats Agreement

(EUROBATS). This agreement recognises that bat species can only be fully protected if their migratory range is protected. Under this agreement, strategies for monitoring bat populations of selected species have been reviewed and standardised methodologies have been recommended (Battersby, 2010). Across Europe, bats are further protected under the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention 1982), which, in relation to bats, works to conserve all species and their habitats.

To fulfil international obligations under the Convention on Biological Diversity and Agenda 21 agreed in 1992, Local Biodiversity Plans must be devised. The 1992 global agreement requires signatory parties to "identify components of biodiversity … and monitor, through sampling and other techniques, the components of biological diversity identified" (Article 7).

The first Irish Red Data Book of Vertebrates (Whilde, 1993) listed the populations of all Irish bats species that were known to occur at the time as Internationally Important.

Marnell *et al*. (2009), in the most recent Irish Red List for Terrestrial Mammals, lists the status of most Irish bat species as 'Least Concern' excepting Leisler's bat (*Nyctalus leisleri*) which is ascribed 'Near Threatened' status. Also, Brandt's bat (*Myotis brandtii*), the status of which is unclear in Ireland, is described as 'Data Deficient'.

Red & Amber Alerts

Under the Habitats Directive, Member States are required to identify species declining at >1% per year. Such a decline would put a species into the "Red" category. However, at this early stage in assessment of brown long-eared bat populations, assessing trends to this level of accuracy would not be statistically sound. Therefore, it is more appropriate to use a standard measure of population trends.

Many standard measurements of population trends are widely used. Rates of population change are regularly used as indicators of the conservation status of species e.g. the conservation alerts defined by The British Trust for Ornithology (BTO). The BTO has developed Alert Levels based on IUCN-developed criteria for measured population declines. Species are considered of high conservation priority (i.e. Red Alert) if their population declines by 50% or more over a 25-year period. Species are considered of medium conservation priority (i.e. Amber Alert) if there is a decline of 25-49% over 25 years (Marchant *et al.*, 1997). A 50% and 25% decline over 25 years translates into an annual decline of 2.73% or 1.14% respectively. These Alerts are based on evidence of declines that have already occurred or can be predicted to occur based on statistically robust monitoring data that is sensitive enough to meet Alert Levels.

The alert system used in this report is designed to draw attention to population declines or increases that may be occurring. It is based on statistical analysis of the population trend of the species being monitored (i.e. brown long-eared bats) seeking to identify rapid declines (>50%) or moderate declines (>25% - <50%) or long-term increases/recovery over specified periods of time. The alerts are calculated regularly using specific statistical procedures and the precision of these methods are reliant on the accuracy and representativity of the data (Baillie & Rehfisch, 2006).

Monitoring data should be of sufficient statistical sensitivity (and better, if possible) to meet these Alert levels. The 2009 Annual Report (Aughney *et al.*, 2010) included power analysis to evaluate the number of brown long-eared roosts that need to be monitored to achieve this sensitivity. Power Analysis indicated that the target of 30-50 roosts counted twice annually should provide robust data to determine red or amber alert declines, or 50% increases in brown long-eared populations. This analysis has been revisited for the present synthesis report. Up to 2009, there was insufficient data collated to determine trends in brown long-eared populations. However, with four years of data now available, trends in brown long-eared populations have been investigated and are presented in this report.

Factors Influencing the Design of the Brown Long-eared Roost Monitoring Scheme

Bat Conservation Ireland manages two other bat monitoring schemes. The Car-based Bat Monitoring Scheme for the Republic of Ireland, in operation since 2003 (Catto & Russ, 2004; Roche *et al.*, 2011), provides a method of monitoring bat species that use habitats along road networks i.e. Leisler's bat, common pipistrelle (*Pipistrellus pipistrellus*) and soprano pipistrelle (*P. pygmaeus*). The All-Ireland Daubenton's Bat Waterway Survey addresses the requirement to monitor the Daubenton's bat (*Myotis daubentonii*) (Aughney *et al.*, 2007).

The survey methodology and roost selection methods used for this monitoring scheme, however, are influenced by the following ecological and morphological factors in relation to brown long-eared bats:

Echolocation Calls & Detection

Many bat monitoring schemes (e.g. Anon, 2009; Roche *et al*., 2011) rely on the use of bat detectors (heterodyne/frequency division/time expansion) to identify the characteristic echolocation calls of a particular bat species. Bat detectors convert the echolocation calls of bats into sounds that are audible to humans (Elliott, 1998). The echolocation calls of bats tend to be outside the human hearing range because the human ear is sensitive to sound frequencies from approximately 40Hz to 20,000Hz (20kHz). The most commonly used bat detector type is the heterodyne bat detector. Others are Frequency Division and Time Expansion.

The brown long-eared bat is often known as the 'whispering bat' because its sensitive hearing enables it to locate prey by passive listening (Anderson & Racey, 1993). As a consequence, its echolocation calls are of low intensity (Russ, 1999). Brown long-eared bats typically produce short duration (2ms) frequency modulated (FM) echolocation calls sweeping from about 80 to 20 kHz with a prominent second harmonic (Ahlén, 1981). FM pulses are usually used by bats in cluttered environments, are commonly associated with gleaning species, and are considered to be an evolved counter measure to detection by tympanate moths (Anderson & Racey, 1993). However, the low intensity calls of the brown long-eared bat means that the detection of such calls by bat detectors is limited to a distance of approximately 0.7m and the main axis of sound emitted by the bat is directed within approximately 120° of the front of the receiving microphone of the bat detector (Anderson & Racey, 1993). Therefore, relying on bat detectors to monitor hunting brown long-eared bats is problematic and, as a result, a foot or car-based bat monitoring survey for this species will not yield sufficient data to allow monitoring of species trends.

Roost Preferences

Brown long-eared bats rely heavily on sinanthropic (artificial) roosts (Swift, 1998). The natural summer roosts of this species are generally tree holes. However, artificial roosts such as attic spaces have replaced many natural structures and in some ways may even be more beneficial than natural tree holes. Attics can provide the more stable thermal conditions necessary for maternity roosts while allowing young bats to practice flying safely before leaving the roost. This species is described as a 'fissure rooster' maintaining constant contact with roof beams on both sides. As a result, brown long-eared bats are more frequently found roosting in the apex of the roof, in the angle between the ridge beam and the rafters or at the gable ends between stone walls and wooden beams (Swift, 1998).

Emergence Times

Average emergence times differ between bat species but brown long-eared bats have been recorded emerging only when it is fully dark during the summer months. Entwistle *et al.* (1996) reported that the average time for emergence varied between roost sites and that there was a high correlation between emergence time and distance from the roost to the closest woodland. The main prey items for this species are Lepidopterans and this prey tends to be available later in the night. Therefore, early emergence is not of great benefit for this species. In addition, emergence is delayed during inclement weather with rain inhibiting flight (Entwistle *et al.*, 1996).

Travel Times

The slow flight of brown long-eared bats may limit the distance that this species can travel at night-time. However, its manoeuvrability means that it can access cluttered habitats. Entwistle *et al.* (1996) reported that 92% of bats within their study area spent most of their time within 1.5km of the roost while the greatest distance flown by an individual (male bat) was 2.8km from the main roost.

Roost Monitoring

Brown long-eared bats show a high degree of roost fidelity and will often use traditional roosts in the long-term (Entwistle *et al.*, 2000). This, coupled with the fact that the species roosts within the attic spaces of buildings, provides a potential means of monitoring populations by counting emerging bats at traditional roosts.

However, the brown long-eared bat tends to be a difficult species to count while emerging from a roost because

- it often uses multiple exit points
- it is difficult to detect by bat detector and
- it emerges late after sunset making it more difficult to be observed visually in low light conditions.

This species also tends to choose roosting sites with large open voids and such voids often have blow fly, spider and harvestmen populations that the bats will glean from surfaces. The presence of such prey items can provide enough sustenance for individuals to remain in the roost during unfavourable weather such as rain, cold weather and windy conditions. Therefore, internal validation of roosting individuals may provide additional information in relation to roosting numbers for this species.

Roost colony counts have been included as part of the BCT's NBMP (National Bat Monitoring Programme) since the late 1990's. The long-eared bat is one of the species monitored using summer roost counts there. In the UK counts are carried out just once annually, in June (Anon, 2007). According to the BCT from Power Analysis carried out in 2001, forty core sites need to be counted annually in order to derive robust trends. Count data is included in the trend model there when counts have been carried out for at least two years (Anon, 2009). In comparison with other species that are highly mobile (i.e. move roosts frequently), such as the common or soprano pipistrelle, the trend data derived from roost counts of brown long-eared bats is considered to be reasonably robust. For common and soprano pipistrelles both species have registered declines according to colony count trend models but have shown increasing and stable trends, respectively, according to field monitoring data. This probably arises from the fact that yearly counts at the same roosts fail to account for roost abandonment, a frequent occurrence among these pipistrelle species.

Potential Problems with Monitoring from Colony Counts

By choosing roosts with high numbers of bats (≥8), which may occur in optimal habitats or areas, there is a possibility that population declines in sub-optimal areas will not be picked up by a survey design based on roost counts. Also, such a survey is inherently non-random since the known roosts are deliberately selected for monitoring. Any bias introduced to the dataset as a result of non-random selection may, potentially, be counteracted by using a sufficiently large dataset (Battersby 2010). For any colony count-based monitoring scheme there is a possibility that roosts will be lost over time as bats move from one site to another. There is therefore an inherent risk that either:

a. bats have abandoned the roost but are still present elsewhere in the locality though not counted, but addition of zero counts to the dataset could result in a false decline being detected.
b. bats have, in reality, declined but the roost is simply recorded as having being abandoned and zero counts are not included in the trend dataset, therefore a population decline is missed.

Power analysis can provide information on the accuracy of the data for informing specific declines or increases. However, as with any monitoring survey methodology, reliable results can best be derived from repeated surveys, over years, at the same location. Battersby (2010) recommends that colony counts at maternity roosts should take place prior to parturition to avoid skewing of results from inclusion of newly volant young, although counts carried out pre and post-parturition may allow some determination of colony productivity.

Volunteers

The methodology of the Daubenton's Bat Waterway Survey scheme is relatively simple and was designed as such by the Bat Conservation Trust in order to attract large numbers of volunteers with little experience in using bat detectors. However, due to the quiet echolocation calls produced by the brown long-eared bat and their tendency to emerge later in the evening compared to other bat species, detection and accurate identification of this species is considered to be more difficult. Volunteers are therefore required to have more experience in bat detection and identification in order to participate in the brown long-eared bat roost counts. Despite a potential training cost associated with recruiting volunteers, this component is thought to be essential in order to ensure the scheme's future cost-effectiveness.

Weather Conditions from 2007 to 2010

Weather data from Met Éireann was incorporated in the analysis (www.meteireann.ie). Mean air temperatures for 2007 were just over one degree above normal compared with the 1961-90 period. This was despite a relatively cool summer, especially over the eastern half of the country. April was the warmest on record at most stations, while the autumn months between September and November were also exceptionally warm. July was the only month when mean temperatures were below normal over most of the country. Annual rainfall totals were above normal over most of Leinster but were well below normal near southern and south-eastern coasts. The distribution of rainfall over the year was very uneven. The summer period of June, July and August was exceptionally wet, especially over the eastern half of the country, where more than twice the normal rainfall for the period was recorded at some stations. In contrast, the subsequent months of autumn were very dry and it was the driest autumn for more than 30 years in many places.

In 2008, annual rainfall totals were above normal everywhere and it was the wettest year for between six and 22 years generally. The distribution of rainfall over the year was very uneven; after a relatively dry spring, there followed a spell of very wet weather between late May and mid-September. The summer period of June, July and August was exceptionally wet for the second year running and it was the wettest summer at Dublin Airport for 50 years. Mean air temperatures for the year were around half a degree above normal at most stations, but it was nevertheless the coolest year for between six and 14 years generally. The mean temperature for most months was around half a degree higher than normal, but May was the warmest on record at most stations, with mean temperatures over three degrees above normal in western areas. Mean temperatures were around normal in June and September.

In 2009 annual rainfall totals were well above normal for the second successive year. Like the previous two years, the summer period of June to August was extremely wet. The exceptionally heavy rainfall brought extensive flooding during the late summer and again during November, especially in the west and south. The driest months relative to normal were March and September, but the annual number of wet days (days with 1mm or more rainfall) was above normal everywhere, by between 10% and 20% generally. Despite very cold weather at the end of the year, mean annual air temperatures were around half a degree above normal at most stations. Mean values were close to those of 2008. Mean air temperatures for most months were slightly higher than normal excepting some of the winter months.

2010 began and ended with spells of exceptionally cold weather, but the months between April and September were warmer than normal. The months of January, February and November were the coldest for at least 25 years, while December was the coldest on record. There was a total of between 75 and 100 air frosts at most inland stations during the year, twice the average amount. The warmest months of 2010 relative to normal were June and September, but many stations recorded their highest daily values unusually early in the year, on either May 22nd or 23rd. Rainfall totals for the year in Ireland were below normal almost everywhere. Around 95% of the normal annual amounts were recorded at most stations, but Cork Airport's total of 905mm, representing just 76% of average, was the lowest on record at the station. The months of January, February, May, October and December were all drier than normal, while only July and November were relatively wet.

Aims of the Brown Long-eared Roost Monitoring Scheme

1. Provide a method of monitoring that collates data that is reliable, repeatable and cost effective.
2. Provide a method of assessing buildings to determine their suitability for monitoring.
3. Provide a list of buildings suitable for monitoring brown long-eared bats.
4. Ensure sufficient data is collected that will allow early recognition of Red and Amber Alert declines in brown long-eared bat populations.

5. To determine population trends.

The Aims of this Synthesis Report

This is the first synthesis report for the Brown Long-eared Bat Roost Monitoring Scheme. For more detail on previous years of the scheme see the Irish Bat Monitoring and Recording Schemes Annual Reports (Aughney & Roche, 2008; Aughney *et al*., 2009 and Aughney *et al*., 2010 available at www.batconservationireland.org/pubs/reports).

This report synthesises the data collected from 2007-2010 and

1. Examines volunteer time and effort
2. Reviews total number of brown long-eared bats counted
3. Examines the methodology utilised by surveyors
4. Examines the use of automated recording devices
5. Reviews the buildings monitored
6. Reviews the buildings surveyed but excluded from the monitoring scheme
7. Looks at population trend data
8. Revisits Power, to detect both Alert level decreases or population increases
9. Assesses the percentage woodland/forestry habitats within selected distances from roosts
10. Examines factors that may influence average brown long-eared bat roost count numbers
11. Makes recommendations on the future of the monitoring scheme.

Methods

Preliminary Roost Assessment

Brown long-eared roosts selected and surveyed in this monitoring scheme were collated from a number of sources:

- BCIreland database
- BCIreland committee members
- NPWS regional staff
- General survey of buildings deemed suitable for this bat species

When good historical data was available for brown long-eared roosts on the BCIreland database, these buildings were included in the monitoring dataset, therefore the selection of roost sites was not random. Additional roost records depended on BCIreland committee members and NPWS regional staff knowledge and therefore tended to be biased towards certain counties (e.g. County Cork). The concentration of buildings surveyed in certain counties was due to the location of surveyors available in such counties. County Cavan, in particular, is well represented due to the fact that the scheme co-ordinator was based in this county and therefore suitable buildings located in this county were targeted. In addition, certain buildings, such as churches, were easier to access and therefore are also well represented. Due to the fact that four or five churches in a particular area tend to be managed by the same priest or rector, access to one church sometimes led to access to all churches under his/her guardianship. This, therefore, influenced the clusters of buildings surveyed in particular areas (e.g. Counties Cavan and Wexford).

Roost owners and/or managers were contacted prior to survey visits to determine whether selected buildings could be included in the monitoring scheme. A roost visit was then undertaken to determine the suitability of the building for monitoring.

All new roosts, when first considered for inclusion in the monitoring scheme, were assessed by completing a daytime check of the building. This involved a survey of the roof space and when the building was accessible, safe, and brown long-eared droppings or actual brown long-eared bats were observed, then a preliminary assessment was undertaken. The preliminary assessment involved surveying the building by using at least two of the methods listed in Table 1 below. Once a site was deemed suitable for inclusion in the scheme (i.e. more than eight individuals were present and it was possible to safely count bats at the site by watching emerging bats or by entering the roof space), monitoring was then completed year-on-year using the most suitable method with an aim of counting the colony at each roost twice per year.

Table 1: Methods of assessing the most suitable protocol for counting brown long-eared bats at each roost. The assessment is carried out using at least two of Methods A-C below. Dates for surveying: Survey 1 1st May to June 15th, Survey 2 June 16th to July 31st, Survey 3 August 1st to Sept 15th.

	Method A	**Method B**	**Method C**
Description	Interior daytime count	Emergence Dusk Count	Interior Post Emergence Count
No. of counts per season	2	2 or 3	2 (usually in conjunction with Method B)
Dates when counts can be conducted	Survey Period1 & Survey Period 3	Survey Period 1 (preferred), Period 2 and Period 3 (preferred)	Survey Period 1 & Survey Period 3
Surveyor	Licensed	Licence not necessary	Licensed
Method	Count of bats present in roost.	Surveyors present at all known exit points, surveying starts 20 minutes after sunset. Count in 10min blocks. Count for 60mins or stop when no bats emerge for 10mins. Note if bats are seen or just heard. Direction of flight also noted.	Enter roost at start and end of emergence. Count bats present on both occasions. Numbers of bats before and after emergence are compared with total observed emerging.
Equipment	Red-light torch	Bat detector and red-light torch	Red-light torch
Other recorded details	Internal roof details, dimensions, presence of roof felt etc.	Weather conditions.	Weather conditions
Other info	Dead bats collected	Fine weather survey only.	Only undertaken in buildings with safe access in hours of darkness.

Annual Roost Counts

Once the assessment outlined in Table 1 is completed, roosts that are suitable for inclusion in the scheme are monitored yearly by either Method A (2 counts) or Method B (2-3 counts) during the specified survey periods. In general, buildings with no access to the roof space are surveyed by Emergence Dusk Counts (Method B) only. Buildings with exit points too high to clearly see emerging bats (i.e. greater than 2 floors high) are monitored using Internal Counts (Method B) if the roof space is accessible. Not all individual brown long-eared bats leave the roost site every night, especially during poor weather conditions (Entwistle *et al.*, 1996) therefore internal validation is completed where possible. Buildings with both access to roof space and visible exit points are assessed by whichever method that can be used with greatest ease and that results in reliable roost numbers. On completion of surveys, survey forms are returned to BCIreland for analysis and reporting.

AnaBat Frequency Division Bat Detectors

Due to the large survey effort required to survey 40 plus roosts twice annually, the potential use of automated recording equipment was investigated as an alternative method to observer counts. An AnaBat SD1 Frequency Division Bat Detector was deployed at two roost sites (roost site code 2029 and roost site code 2013) for three counts in 2009 and four counts in 2010. Roost Site Code 2029 is an agricultural building and the brown long-eared bats roost in the loft. The exit point is an open window and bats travel to the rear of the building directly into a treeline located 5m from the exit point. From observations in 2008, all emerging bats followed the same commuting route. The AnaBat unit was located directly in line of this commuting route from the building. The surveyor (scheme co-ordinator) is also located at this point to record emerging bats.

Roost Site Code 2013 is a church and the brown long-eared bats roost in the attic space. All of the bats exit from the bell tower but tend to exit to one side of the bell tower, fly low to the ground and commute directly into the closest treeline located approximately 6m from the church. Occasionally, individual bats were recorded exiting from the opposite side of the bell tower. The AnaBat unit was located directly below the bell tower in line with emerging bats. The surveyor (scheme co-ordinator and local volunteers) is located in front of the bell tower allowing both potential exit points to be surveyed.

For colony counts the AnaBat unit was set to record for the same length of time as the surveyor. Recordings (to Compact Flash Card) were downloaded and analysed using Analook software. Each time-stamped file with a brown long-eared bat echolocation call was recorded as an individual observation. The number of recorded observations was then directly compared to the number of individual bats recorded emerging from the roost by the surveyor. The surveyor used a Petersson D240x Time Expansion/Heterodyne bat detector with ear phones to prevent any interference with AnaBat recordings.

Statistical analysis of AnaBat count numbers was carried out using DataDesk 6.

Power Analysis

Power Analysis uses, as its basis, information about how much sites vary from year to year. In general, this involves estimating the patterns of variability in the real data using REML analysis and then simulating a large number of artificial datasets with added trends. GAM models are then fitted to the artificial datasets to see how frequently the trends are detected with different numbers of sites and years.

The two standard levels of decline – Amber Alert, representing a 25% fall over 25 years (i.e. 1.14% per year), and Red Alert, representing a 50% fall over 25 years (i.e. 2.73%) per year) – are used as the basis for the Power Analysis.

Power Analysis was completed on brown long-eared count data collated since 2007 (2007-2010 dataset) and simulations for various numbers of roosts and years was undertaken. The simulated data is designed to have similar means and variances to the real data. In detail, simulations are based on the variance components from a REML model of bat counts per survey, transformed using normal scores (see for example Armitage and Berry, 1987) and estimating variances for sites, sites within years and replicate surveys within sites within years. Data are simulated using these variance estimates and back-transformed to the original scale after adding suitable year effects in order to produce the required long-term trend. Uncertainty in the estimates of variances can lead to erroneous estimates of power (Sims *et al*., 2006) and so each simulated dataset is based on variance estimates taken from a bootstrapped version of the original dataset, thus ensuring that the power results are effectively averaged over a range of plausible values of the variance estimates.

GAM models are then fitted to the simulated data, using bootstrapping to produce a one-tailed test for a decline at $P = 0.05$ (equivalent to $P = 0.1$ for a two sided test). Calculations are based on a GAM analysis of trend over time (rather than REML), although a REML model is used as the basis for the simulations. In order to find the number of years required to achieve 80% power for each number of sites, a sequential method (based on a modified up-and-down method, Morgan, 1992) is used to determine the number of years of data to include in each simulated dataset, ensuring that precise estimates are obtained with the minimum number of simulated datasets. The final estimate of power is then taken from a logistic regression of the probability of obtaining a significant decline against the number of years of data included in the simulation.

All GAM curves used the default degrees of freedom (0.3*nyears). Because GAM trends are estimated with less precision in the first and last years of a series, the second year is used as the base year in the simulations, and the trend is estimated up to the penultimate year.

The simulations are based on all the data collected so far i.e. internal counts and emergence dusk counts. Hence the power results assume that the mix of internal and external counts will remain as at present. Power Analysis was carried out using GenStat v. 13.

Trend Analysis

To assess trends a Generalised Linear Model (GLM), with confidence limits based on bootstrapping at the site level was applied to the data collated from 2007-2010. To allow for differences between Internal Counts and Emergence Dusk Counts, and between the different periods (S1, S2 and S3), all counts for roosts monitored for at least two years, are included in the model. Trend analysis was carried out using GenStat v. 13.

GIS Analysis

GIS mapping of nearest woodland/forestry habitat and area of woodland/forestry (ha) was completed on monitored roosts in relation buffer zones at radii of 0.5km, 1km, 1.5km, 2km and 2.5km. This analysis was completed using ArcView 9.2 with coverage based on data collated from the NPWS Native Woodland Inventory and the Forest Service Forest Information Planning Service (FIPS). In addition, using 2005 aerial photographs, the shortest distance from the roost via a linear landscape feature (treelines and hedgerows) to the nearest woodland block (both FIPS and Native Woodlands) was calculated.

Brown Long-eared Bat Habitats and Roosting Requirements

The aim of this analysis was to determine whether any factors such as building characteristics or habitat coverage within known distance of the roosts could be used as predictors of average roost numbers. Results from roosts that were counted in both 2009 and 2010 were collated into a dataset for this analysis. Roosts where at least three counts have been carried out in 2009 and 2010 were included and roost counts prior to 2009 were not included in order to ensure consistency in the dataset. In total, 35 roosts were suitable for inclusion. Counts were averaged for the two years so that there was one data point for each site.

Possible predictive factors for initial investigations of the data included:

- Building type (including Church, Farm Building, House, Large Mansion etc.)

- Wall construction: Concrete or natural stone
- Age in one of two categories: >100years or <100years
- Presence of roof felt
- Roof covering (natural slate, natural stone, modern slate, galvanise)
- Grid reference eastings and northings
- Rural/Urban Edge/Urban Centre
- Habitat Data at Two Spatial Scales:
    - Within a 500m radius of the roost, tall vegetation categories such as hedgerows, treelines, small woodlands and parkland trees were digitised using aerial photographs to determine their total cover. Cover of FIPS woodlands was categorised according to types (e.g. mixed, deciduous etc.).
    - Within 2.5km radius of the roost. Hectares of woodland/forestry within specified distances (0.5km, 1.0km, 1.5km, 2.0km, 2.5km) from the roost; commuting distance from roost to nearest FIPS polygon collected from GIS and aerial photography, and size of nearest FIPS woodland block.

One way ANOVAs were carried out on roost category variables and Principal Components Analysis was carried out with habitat variables at the two spatial scales. Significant, factors and/or components were investigated for potential usefulness in combination in a General Linear Model (ANOVA or ANCOVA). Continuous variables such as woodland cover (hectares) were square root transformed to conform to requirements for normality. Count data was log-transformed. These analyses were carried out using DataDesk 6.

Results

Volunteer Participation

For volunteer teams, training was provided on-site, with the scheme co-ordinator and volunteers completing the first count together. Bat detectors and torches were provided by BCIreland, where required. In addition, the co-ordinator accompanied many volunteer team counts during the first survey of each new monitoring year to provide continued support (n=26 training surveys). The number of roosts surveyed in each year of the monitoring scheme and the number of volunteer teams participating generally increased from year to year. In total, 80 volunteers participated in the monitoring scheme from 2007-2010.

In 2007, 35 volunteers participated in the monitoring programme. Data was also collected on 18 brown long-eared roosts and the VWT Bat Box Schemes of Portumna Forest Park and Garryland Woods, County Galway. The 17 brown long-eared roosts monitored were distributed in 11 counties. The Cork County Bat Group was allocated three roosts and Galway Bat Group monitored one roost. Two roost owners participated in the scheme in 2007 while an additional six roosts were monitored with volunteer assistance. All other roost counts were completed by the co-ordinator of the scheme (n=5).

Thirty three volunteers participated in the monitoring programme in 2008. The Cork County Bat Group was allocated two roosts for monitoring within the county and Galway Bat Group monitored one roost. Two roost owners participated in the scheme in that year while an additional thirteen roosts were monitored with volunteer assistance. All other roost monitoring was completed by the co-ordinator of the scheme (n=17).

In 2009, 45 volunteers participated in the monitoring programme. The Cork County Bat Group and Galway Bat Group were allocated two roosts each within their counties. Clare and Dublin Bat Groups were allocated one roost each. Three roost owners counted their own roosts in 2009. Five additional teams monitored a further eight roosts. Seventeen sites were, therefore, counted by volunteer teams while all remaining roosts were counted by the co-ordinator of the scheme (n= 23).

Thirty eight volunteers participated in the monitoring scheme in 2010. The Cork County Bat Group and Galway Bat Group were allocated two roosts each within their counties. Clare, Abbeyfeale and Dublin Bat Groups were allocated one roost each. Five house owners counted their own roosts in 2010. Eight additional teams monitored a further 10 roosts while all remaining roosts were counted by the co-ordinator of the scheme (n=23).

Volunteer Training and Survey Time

Yearly training was offered to volunteer teams to ensure that participating surveyors were confident and competent in surveying the roosts allocated to them. A total of 26 training surveys were completed over the duration of the monitoring scheme. Before any roosts were assigned to volunteer teams, the co-ordinator surveyed the roosts in order to collect as much detailed information as possible for individual buildings. Of the 252 monitoring surveys completed in 2007-2010, 143 (57%) were completed with volunteer assistance (Team size ranged from 2-5 people, Average Team size = 2.6 volunteers). This amounted to a total of 321 hours 15 minutes (19,275 minutes). This figure does not include travel time or survey preparation and only refers to actual survey time[1].

Volunteer Contribution: A Financial Perspective

Costing in travel (assuming that volunteer team's car share) and survey preparation at an additional 3 hours per survey should be included. This adds a further 429 hours. The total volunteer contribution is then 750 hours 15 minutes. If all volunteer surveyors involved were paid the current minimum wage for the Republic of Ireland (€7.65 per hour), this would total €5,739.41 (excluding employer's costs) over four years of the survey. If we add a nominal sum for mileage costs per survey at just €10, then we can add another €1,430 to this figure with a total of €7,169.41. If the survey were to rely on professional bat specialists or ecologists to complete the monitoring schedule the financial contribution and the time allocated to surveying each building would increase dramatically (due to travel, over-night accommodation and increased hourly costs for employing professionals etc.).

[1] The length of survey time for External Dusk Counts was recorded and this ranged from 50-90 minutes. Internal Counts were set at 30 minutes each for ease of calculations.

Buildings Surveyed

During the 2007-2010 period a total of 118 buildings were investigated and 57 of these were monitored. Each year of the scheme, additional roosts were investigated to add new brown long-eared roosts to the dataset as suitable for monitoring. A total of 61 additional buildings were assessed and deemed unsuitable.

Roosts Monitored

During the 2007-2010 monitoring period a total fifty-seven of these were monitored. The roosts are located in 21 counties with the highest number of roosts located in County Cork (n=10). While there is a clustering of roosts in some counties, overall the national distribution of the roosts is statistically valid.

The overall number of roosts monitored increased each year. The number of roosts monitored by External Counts also increased each year and this tended to be the preferred method of monitoring (See Figure 1). Internal Counts were completed within 30 minutes while the average time taken to complete External Counts was 70 minutes (Range 50-90 minutes).

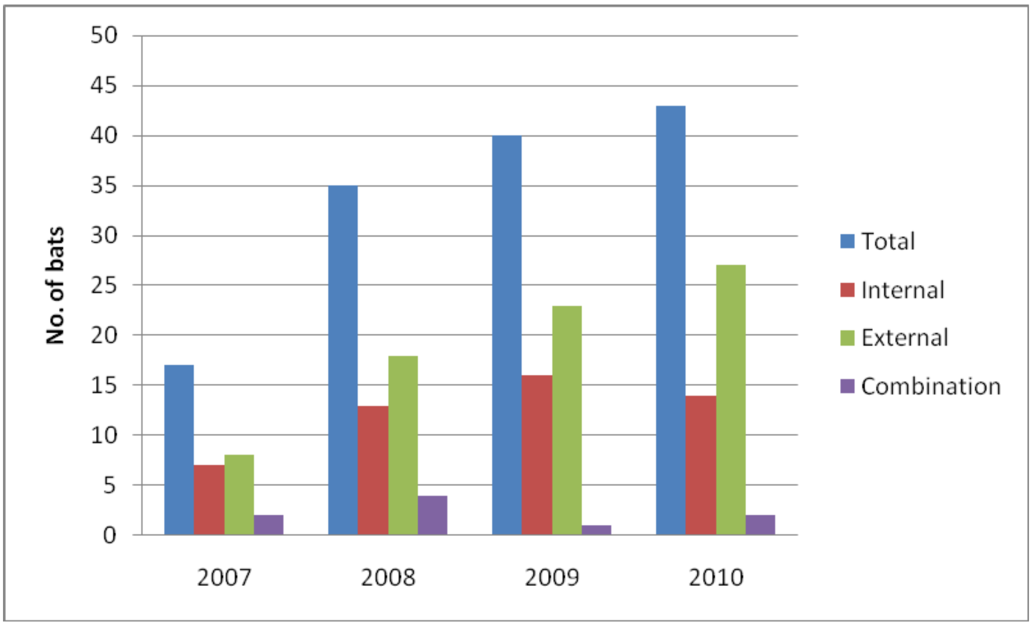

Figure 1: Total number of roosts monitored from 2007 to 2010 and number of roosts monitored by each survey method.

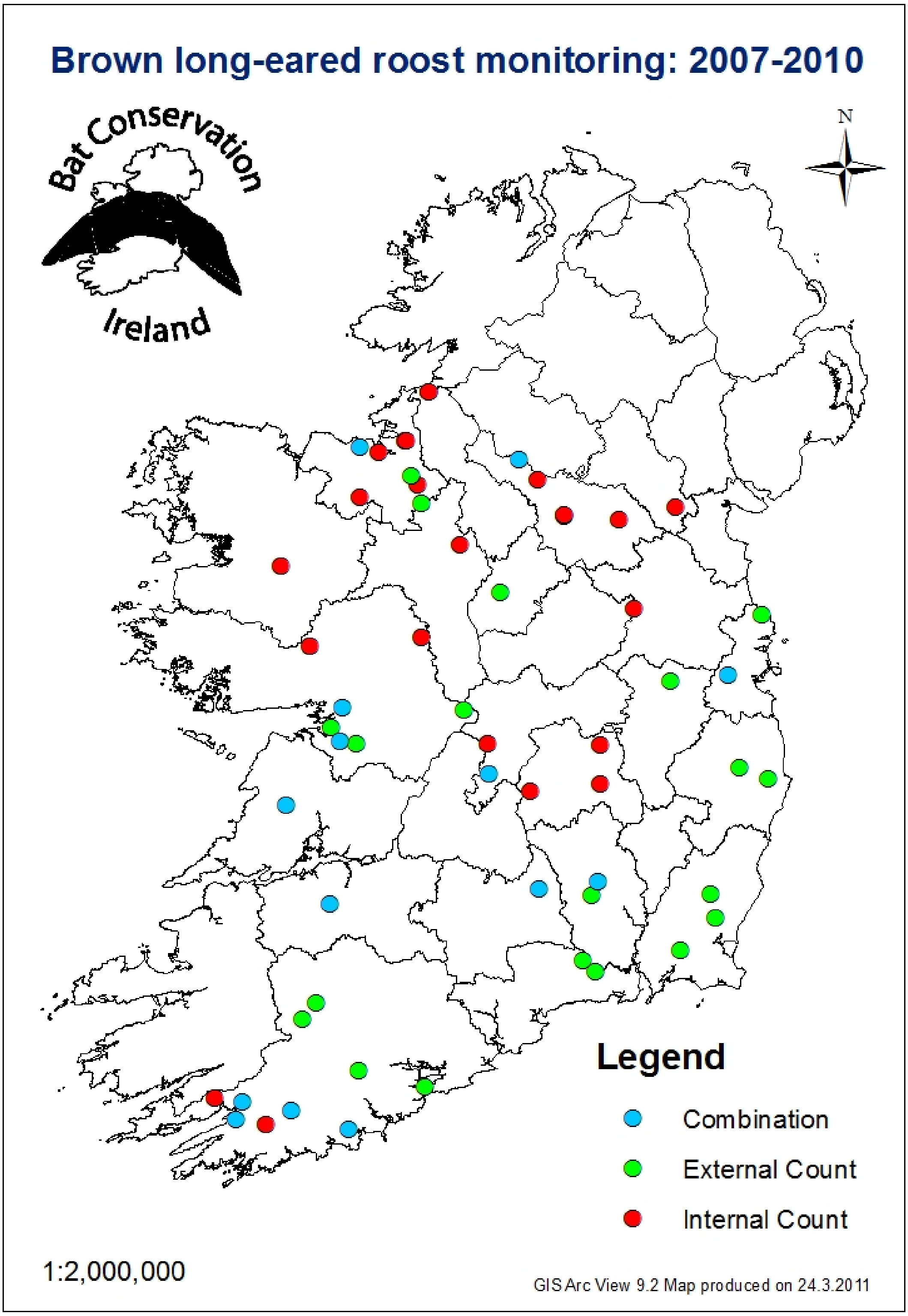

Figure 2: Location of brown long-eared roosts monitored from 2007-2010, colour coded according to survey methodology used to carry out roost counts.

Table 2: Summary of total number of roosts monitored and surveys completed for each year of the monitoring scheme (2007-2010)

Year	**Total No. Roosts**	**Total No. Surveys**	**Internal Counts**		**External Counts**		**Combination**
			Roosts	Surveys	Roosts	Surveys	Roosts
2007	17	27	7	12	8	15	2
2008	35	55	13	31	18	24	4
2009	40	78	16	29	23	49	1
2010	43	92	14	30	27	62	2

In 2007 a total of 17 roosts were monitored and taking the highest count for each roost, the total number of bats counted in 2007 was 348 individuals. Both the number of roosts and the number of individual bats have increased since 2007 as shown in Table 2 above. A total of 759 individual bats were counted in the 35 roosts monitored in 2008 and this increased to 1,125 individuals in 2009 (n=40 roosts). In 2010 the highest number of roosts was monitored with total of 43 roosts counted by 62 external dusk counts and 30 internal counts yielding a total of 1,481 individuals. Over the four years of the scheme, a total of 252 surveys were completed, 102 by internal counts and 150 by external counts.

In total, 57 roosts were monitored from 2007 to 2010. Table 3 lists roosts according to the number of years of monitoring completed to-date. To improve the statistical robustness of the monitoring scheme, it is better when the same sites are monitored from year to year. For the current dataset, 19.3% of roosts (n=11) have been monitored for all four years of the scheme. Less than half of the dataset (n=25, 43.9%) were monitored for three or more years but these roosts have proved to be suitable for the monitoring scheme and are likely to be included in any future monitoring scheme for the species.

Table 3: Number of years of data collated for each roost monitored in 2007-2010.

Number of years	**Number of sites**	**% of total**	**Cumulative %**
1	15	26.3	26.3
2	17	29.8	56.1
3	14	24.6	80.7
4	11	19.3	100.0

Roost Categories

Of the 57 buildings monitored in 2007-2010, Churches were the largest category of the building types surveyed (Table 4). This can be further divided into Church of Ireland churches category (n=16) and these tend to be 18th or 19th century buildings constructed of stone. These buildings often have a bell tower which facilitates bats entering and exiting the roof void. Catholic churches (n=8), the second sub-category, were mainly buildings constructed in the 20th century with large roof voids. The large building/mansion category (n=19) generally consisted of ≥2 storey houses built in the 19th century with large roof voids. The house/bungalow (n=7) category included smaller modern houses (when compared with the Georgian house category) built in the 20th century. Three of the four agricultural buildings were constructed of stone with the remaining one a modern barn located adjacent to a large area of deciduous woodland. The last category (Other) consisted of a building which is a modern warehouse-like building, a medieval tower, a 12th century stone building and a modern community building.

Table 4: Types and percentages of buildings monitored from 2007 to 2010

Building Types	**2007**		**2008**		**2009**		**2010**		**All Years**	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Agricultural building	0	0	2	5.7	4	10.0	2	4.7	4	7.0
Church	5	29.4	12	34.3	21	52.5	19	44.2	24	42.1
House	2	11.8	4	11.4	4	10.0	6	14.0	6	10.5
Large bld/mansion	7	41.2	15	42.9	9	22.5	13	30.2	19	33.3
Other	3	17.6	2	5.7	2	5.0	3	7.0	4	7.0
All Roost Categories	**17**		**35**		**40**		**43**		**57**	

The structures monitored over the duration of the scheme were categorised according to their roofing type, wall construction, age and location. The majority of the buildings surveyed had a natural slate roof, constructed using natural stone, were more than 100 years old and were located in a rural setting. The overall average count was 22.5 bats (n=57 roosts) for all roosts monitored over the duration of the scheme.

Table 5: Average Roost Count for different categories of roost types

Building feature	% of Roosts Monitored	Average Roost Count (2007-2010)	No. of Roosts (2007-2010)
Natural Slate Roof	82.5%	22.56 bats	47
Stonewall construction	80.7%	23.26 bats	46
>100 years of age	64.9%	23.93 bats	37
<100 years of age	35.1%	19.22 bats	20
Rural location	61.4%	26.73 bats	35
Urban Edge location	35.1%	16.28 bats	20
Urban Centre location	3.5%	10.75 bats	2
All Roosts	100%	22.5 bats	57

* Average Roost Count excludes surveys where zero bats were counted

Additional Roosts Surveyed

An additional 61 roosts were surveyed over the duration of the monitoring scheme to determine whether brown long-eared bat roosts were roosting within these structures.

Due to the fact that brown long-eared bats are known to use older buildings such as churches, this structure type was targeted for examination and therefore represents 72.1% (n=44) of additional structures surveyed. Other building types surveyed included 13 (21.3%) in the category 'large building/mansion' and four structures (6.6%) in the 'other' category (principally castles). These buildings were located in Counties Cavan (n=16), Meath (n=1), Longford (n=5), Leitrim (n=3), Laois (n=1) Cork (n=5), Tipperary (n=2), Kerry (n=4), Waterford (n=2), Wexford (n=5), Mayo (n=2), Donegal (n=1), Galway (n=2), Monaghan (n=3), Kildare (n=2), Roscommon (n=2), Clare (n=1) and Dublin (n=3) (See Figure 3)

Twenty-six of the additional buildings surveyed had brown long-eared bat roosts. However, in the majority of cases the roosts consisted of <8 individuals (n=21) while in the remaining five buildings, the emerging bats were too difficult to count and the sites were not, therefore, included in annual monitoring. Of the remaining additional buildings assessed, three buildings were surveyed because historical records indicated that brown long-eared bat roosts were present. However, during this survey scheme, no brown long-eared bats were detected during night-time bat detector surveys. All remaining roosts were inspected as examples of buildings potentially suitable for brown long-eared bats but no brown long-eared bats were recorded while four new bat roosts were recorded in the process (one whiskered bat roost and three soprano pipistrelle roosts).

All of the additional buildings surveyed were >100 years of age, 95% had a natural slate roof (n=58), but a large number of these buildings were located in an urban areas (Urban central: n=21, 34%; Urban edge: n=11, 18%) compared with those roosts included in the annual monitoring, the majority of which were located in rural areas (See Table 5 above).

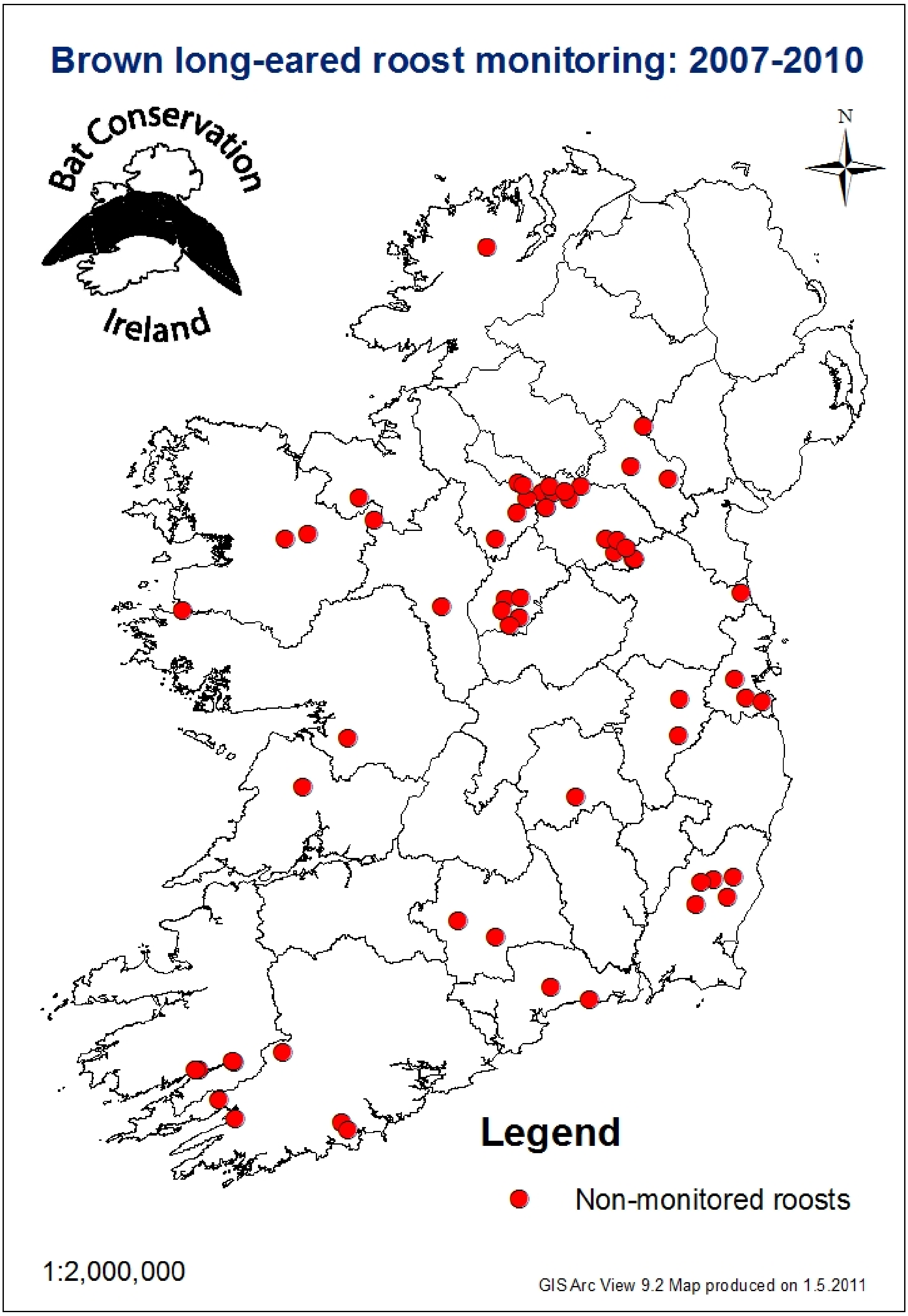

Figure 3: Location of additional buildings surveyed from 2007-2010 for brown long-eared bats but not included in the monitoring dataset.

Roost Colony Size

Taking the highest count for each roost monitored, the total number of bats counted as part of the monitoring scheme was highest in 2010 and the total number of bats was 1,481 individuals (n=43 roosts). Across all roosts and all surveys where bats were present, the total number of bats counted ranged from one to 105 individuals. The mean number of bats counted in each year ranged from 18.04 individuals in 2007 (n= 17 roosts, 1-48 bats) to 31.7 individuals in 2010 (n= 43 roosts, 2-105 bats) (See Table 6).

Table 6: Average roost counts for each year of the monitoring scheme.

Year	Total No. Roosts	Total No. Surveys	Mean Roost Count (range)
2007	17	27	18.04 (1-45 bats)
2008	35	55	18.64 (1-65 bats)
2009	40	78	26.12 (6-81 bats)
2010	43	92	31.7 (2-105 bats)

The majority of roosts, on average, contained 20 or less individuals (n=34, Mean = 11.88 individuals) and these were categorised as small roosts. Medium size roosts (21-40 individuals) was the next category and consisted of 15 roosts (Mean = 30 individuals) while eight large roosts (>40 individuals) were also monitored (Mean = 50.75 individuals).

Ten roosts were counted during each of the four years of the scheme. Taking the maximum roost count each year, the average roost colony size ranged from 26.4 individuals (2008) to 37.7 individuals (2010) (See Figure 4, Table 7 and Appendix 2 for individual site plots). For some of the sites, the counts in the early years of the scheme were low but as more information about the roost and colony behaviour was gathered, the counts increased.

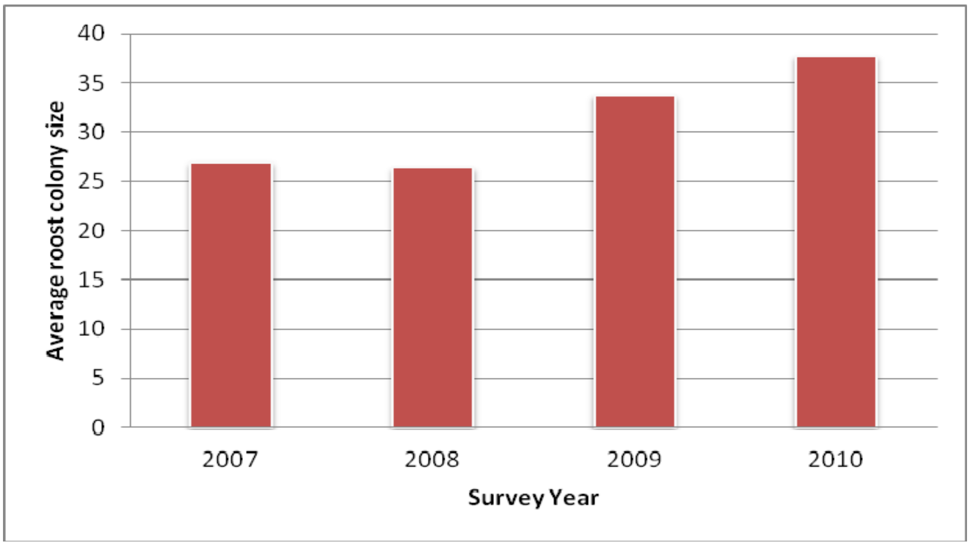

Figure 4: Average roost counts for 10 roosts counted each year of the monitoring scheme.

Table 7: Average roost count for ten roosts counted during each of the four years of the scheme

Roost Site Code	2007	2008	2009	2009
Site Code 2001	27	58	62	60
Site Code 2002	17	14	0	0
Site Code 2003	5	11	20	16
Site Code 2005	35	22	24	29
Site Code 2006	22	18	18	10
Site Code 2009	20	40	21	44
Site Code 2010	34	17	38	40
Site Code 2012	31	28	61	78
Site Code 2013	48	48	34	38
Site Code 2014	30	8	59	62
Mean	**26.9**	**26.4**	**33.7**	**37.7**

Ease of Monitoring & New Roosts

While 57 roosts were monitored over the last four years, not all of these roosts should be included in a future monitoring scheme. Over the course of the past four years, some roosts have become unsuitable for bats while other roosts have proven too difficult to count or require a larger number of volunteers to successfully count than are available. One such example is a roost where bats occupied the building until the adjacent hedgerow was removed. Since then, no bats have been recorded in the roost. Therefore, recording information with regards to land use, adjacent habitats and changes to the immediate environment is important to determine whether the fall in numbers for any particular roost is due to abandonment or actual population decline.

Survey Period

Monitoring surveys were categorised into three periods:

- Survey 1: May 1st to June 15th
- Survey 2: June 16th to July 31st
- Survey 3: August 1st to Sept 15th

Young bats can be assumed to be volant by the time Survey 3 takes place each year, in which case it may be expected that average counts are greater during this survey than during the first which occurs pre-parturition, and the second which may occur prior to some or all young in a roost taking flight. However, in general the counts completed in the Survey 2 period yield a higher average figure compared to the two other survey periods in 2007 and 2008 while the Survey 3 period yielded a higher average figure in 2009 and 2010. As more information was collected about individual roosts, it was found that surveying certain roosts too early in May meant that the maternity colony was not yet established and, therefore, yielded lower counts than if surveyed a little later in the survey period. In addition, it was also found that surveying roosts later during the Survey 3 period could also result in low counts due to the fact some colonies started to leave in early September. Surveying such roosts in August yielded higher counts. Figure 5 below shows average counts per survey period for all years 2007-2010 of the survey to date.

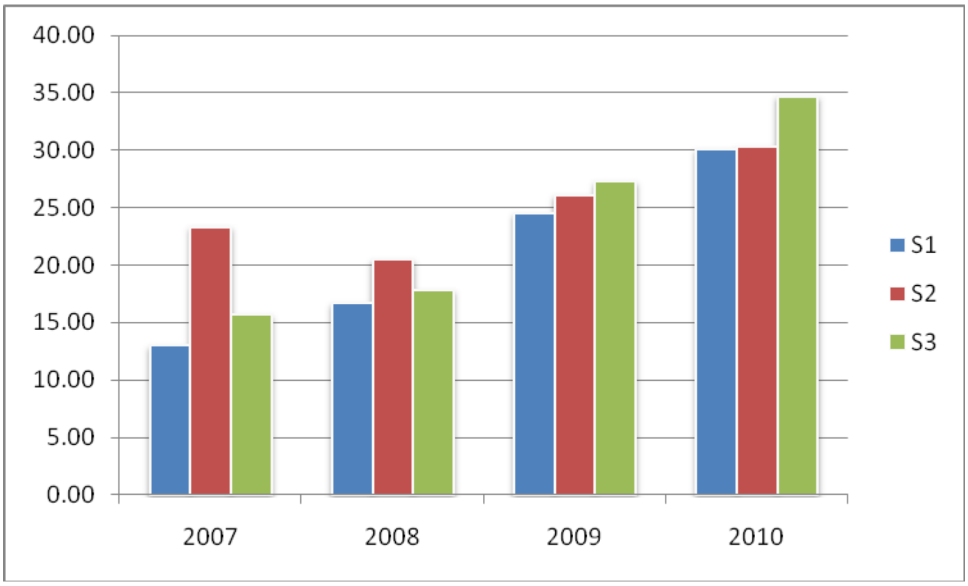

Figure 5: Average roost counts for each survey period for each year of the monitoring scheme (S1: 1st May to 15th June; S2: 16th June to 31st July & S3: 1st August to 15th September).

AnaBat Frequency Division Bat Detector Recordings

On all seven survey dates, the AnaBat unit recorded fewer brown long-eared bats compared to the total numbers recorded by the surveyor (see Table 7). A Wilcoxon Signed Rank test indicates a significant difference between the datasets collected using the two methods (z statistic = -2.3749, p=0.0176).

At site 2029 where the average surveyor's count was 20 bats, the AnaBat recorded on average 17.25 bats (13.75% less). At site 2013 where the surveyor's count averaged 43 bats, the AnaBat recorded an average of 32 (7.7% less) per survey.

Table 7: AnaBat SDI Frequency Division Bat Detector recordings compared to number of bats recorded by surveyors (2009 & 2010)

Roost Site Code	Date	Surveyor	AnaBat SD1
Site Code 2029	10/07/2009	18	17
Site Code 2029	14/09/2009	19	16
Site Code 2029	11/06/2010	19	17
Site Code 2029	12/08/2010	24	19
Site Code 2013	10/09/2009	34	31
Site Code 2013	13/06/2010	33	32
Site Code 2013	04/07/2010	38	32
	Average Count	26.42	23.43
	Standard Deviation	±8.38	±7.76

Power Analysis

Results of Power Analysis using two counts per year with varying number of roosts, based on 2007-2010 count data, are shown in Tables 8 and 9. Individual values are subject to the usual estimating errors so it is necessary to take a broad view of the trend with increasing numbers of roosts, rather than focusing too much on individual values.

Table 8 shows the results of investigations into amber and red alert declines (i.e. 25% or 50% declines over 25 years). Table 9 shows number of years' surveying required to determine a 50% increase over 25 years (assuming each roost is counted twice per annum).

Table 8: Number of years to achieve 80% power for various scenarios based on Bat Conservation Ireland brown long-eared roost data.

	Years for 80% power			
	Red alert		**Amber alert**	
Sites	**Estimate**	**s.e.**	**Estimate**	**s.e.**
20	10.1	0.5	18.5	0.9
30	8.7	0.3	15.9	0.8
40	8.0	0.3	14.5	0.7
50	7.5	0.4	13.0	0.6
75	6.7	0.6	11.1	0.4
100	6.1	0.2	10.7	0.5
125	5.9	0.3	9.9	0.4
150	5.7	0.3	9.6	0.4

* Whilst the number of years must be an integer in reality results are shown here with one decimal place to aid comparisons.

Table 9: Number of years to achieve 80% power for various scenarios based on Bat Conservation Ireland brown long-eared roost data (assuming each roost is counted twice).

	Years for 80% Power	
	50% Increase	
Sites	Estimate	s.e.
20	15.6	0.5
30	13.3	0.5
40	11.7	0.3
50	11.1	0.3
75	9.9	0.4
100	8.6	0.3
125	7.9	0.2

* Whilst the number of years must be an integer in reality results are shown here with one decimal place to aid comparisons.

In theory red alert declines can be detected relatively quickly (in ten years with only 20 sites). Larger numbers are needed for amber alert declines and they can be detected 80% of the time with just over a hundred sites in the same duration. The number of years of surveying required to detect a 50% increase are intermediate between those for red and amber alert declines.

It is worth noting that, as for other monitoring schemes, the impact on Power of adding more survey sites lessens as the number of sites increases. For example, by increasing the number of sites surveyed by 25 from 125 to 150 just decreases the number of years required to detect a red alert decline by 0.3, whereas at lower site numbers (e.g. 20) the addition of 20 new sites (to 40) results in lowering the number of years required for red alert detection by over two years. This effect is even more pronounced for amber alert decline detection. Following on from this, if 30 roosts were surveyed twice annually, then red and amber alert declines should be detectable by 8.7 years and 15.9 years, respectively. If 50 roosts were surveyed twice per year the number of years of surveying required would change to 7.5 years and 13.0 years, respectively. These results are very similar to those calculated in 2010 using 2007-2009 dataset. As a result of an additional year's data and a small number of extra sites, the Power of detecting both Red and Amber Alerts has increased slightly.

The results in Tables 8 and 9 are based on simulations in which each roost is observed twice in every year, whereas missing counts are inevitable in practice. If the missing observations are at random then the impact is roughly proportional to the number of missing counts; for example, if 100 roosts are known but around 20 are not observed in any one year, the Power will be roughly the same as observing 80 roosts continuously. If, as is more likely, the missing observations are non-random (for example, if a roost is observed continuously for five years, then not observed for the next few years), the impact will tend to be much greater.

In view of the current economic climate, funding for the current monitoring protocol may not be available. As a consequence, further power analysis was undertaken to determine the feasibility of a monitoring less roosts either once per year, once every two years or once every three years. The analysis assessed a protocol of counting a minimum of 30 roosts once per year and the results are presented in Table 10. The power of detecting red alerts is reduced considerably for all three events compared to the current scheme protocol. Counting 30 roosts twice annually allows red alerts to be detected in 13.3 years. Counting 30 roosts once a year allows red alerts to be detected in 19 years. This time frame increases to 22.8 years and 27.5 years respectively for 30 roosts counted once every two years and once every three years.

Table 10: Number of years (including the extra years needed at either end of the GAM curve) to achieve 80% power to detect a Red Alert decline for various scenarios with a single count at each roost per year based on Bat Conservation Ireland brown long-eared roost count data.

Years for 80% power						
	Every year		**Every second year**		**Every third year**	
Sites	**Estimate**	**s.e.**	**Estimate**	**s.e.**	**Estimate**	**s.e.**
20	21.7	0.9	26.8	1.7	>28	n/a
30	19.0	1.1	22.8	1.1	27.5	1.0
40	18.4	0.7	21.5	0.9	25.0	0.9
50	15.7	0.5	19.6	1.3	23.1	0.7
75	12.5	0.7	17.1	1.2	20.2	0.7
100	11.8	0.5	15.8	0.9	18.7	0.5
125	11.2	0.4	14.9	1.0	17.2	0.7
150	10.7	0.5	13.4	0.7	15.2	0.3

* Whilst the number of years must be an integer in reality results are shown here with one decimal place to aid comparisons.

Trend Analysis

A simple GAM model was fitted to the data to illustrate the smoothed trend (Figure 6). This needs to be interpreted alongside the unsmoothed annual means (last two columns in Table 11), which are equivalent to the GLM estimates presented last year (See Appendices). Roost counts in 2010 were high on average compared to previous years of the monitoring scheme, and so the smoothed line is heading upwards. This result needs to be treated with considerable caution at this early stage, but is encouraging as there are only four years of data and the dataset is relatively small.

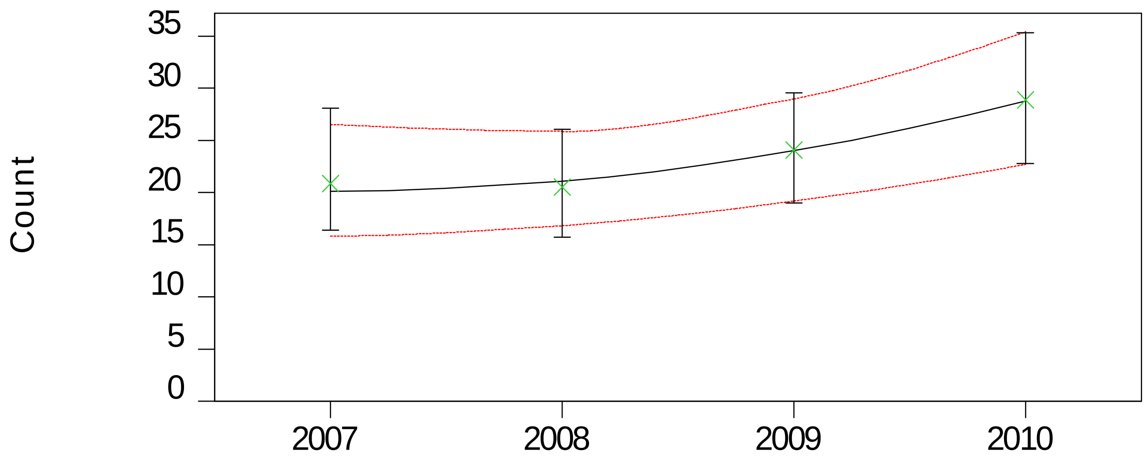

Figure 6: GAM results with 95% confidence limits. Points are estimated annual means and are shown to illustrate the variation about the fitted line.

Table 11: GLM/GAM results with 95% confidence limits for dataset 2007-2010. 42 sites contribute to the model; this excludes sites surveyed for only one year.

					Estimated mean bat count					
					Smoothed		***95% conf limits***		**unsmoothed**	
year	*counts*	*sites*	*Mean*	*s.e.*	*estimate*	*s.e.*	*lower*	*upper*	**estimate**	**s.e.**
2007	25	16	18.3	2.3	20.1	2.7	15.8	26.5	20.9	2.9
2008	50	30	18.8	2.3	21.1	2.3	16.8	25.8	20.5	2.7
2009	73	36	25.6	2.0	24.0	2.5	19.2	29.0	24.1	2.7
2010	80	38	29.8	2.2	28.7	3.3	22.7	35.4	28.9	3.2

Table 11 shows results from a Generalised Linear Model (GLM), with confidence limits based on bootstrapping at the site level. To allow for differences between Internal Counts and Emergence Dusk Counts, and between the different periods (S1, S2 and S3), all counts for roosts monitored for at least two years from 2007-2010, have been included in the model. A smoothed trend has been fitted, given that there are now four years of data available for analysis.

From Figure 6 (and Table 11) it is clear that the fitted mean is slightly higher in 2010, but the difference is small relative to the confidence limits, so this is not significant. Despite the smaller sample size, confidence limits are narrower in 2007 than in 2010. This is because the 2007 counts were less variable, with a high proportion between 10 and 35, and no very large counts.

A Generalised Linear Mixed Model (GLMM) with a Poisson error distribution was fitted to the 2007-2010 dataset to see if the following parameters affect the data: northings and eastings, day number, weather data, start time and internal/external counts. As reported last year, external counts tend to be higher than internal ones (Table 12), but the internal ones tend to be more variable (F = 4.93 with 1 and 220 d.f., P=0.027). No other variables were significant.

Table 12: Effects of factors from the GLMM model: internal v external counts

(F = 4.93 with 1 and 220 d.f., P=0.027)

		Raw data		Adjusted for other variables		
Group	**surveys**	**mean**	**s.e.**	**log**	**s.e.**	**back-trans**
Internal	101	20.9	1.69	1.20	0.046	15.7
External	151	26.7	1.55	1.30	0.044	20.2

* Counts of bats are shown with standard errors, as well as predicted values on the log scale, after adjusting for the effects of other factors in the model (year in this case). The absolute value of the adjusted means is not informative due to the averaging over other terms, but the relative sizes indicate where the differences lie; standard errors are applicable to the log values, but back-transformed values are easier to interpret.

GIS Analysis

Percentage of Woodland & Forestry Habitat

Combining both the Forest Information Planning Service (FIPS) data and Native Woodland Inventory data, the percentage of woodland located within five buffer zones around each of the 57 roosts was calculated. Only a small number of roosts did not have woodland present within a 0.5km radius of their location and this number reduced, as expected, as the buffer zone area increased (See Table 13).

Table 13: The amount of FIPS forestry and Native Woodland Inventory data located adjacent to monitored roosts (n=57 roosts)

Buffer Zone	**Actual Area (ha)**	**Roosts with woodland within buffer zones**		**Average Area of woodland within buffer zone**	
		No.	**% of roosts**	**Ha**	**% of total area**
Buffer Zone 1 – 0.5km radius	78.52 ha	45	78.9%	10.97 ha	13.97%
Buffer Zone 2 – 1.0km radius	314.12 ha	52	91.2%	40.98 ha	13.05%
Buffer Zone 3 – 1.5km radius	706.8 ha	54	94.7%	80.84 ha	11.35%
Buffer Zone 4 – 2.0km radius	1256.55 ha	57	100%	132.49 ha	10.4%
Buffer Zone 5 – 2.5km radius	1963.39 ha	57	100%	186.41 ha	9.49%

Proximity to Woodland & Forestry Habitat: Commuting Routes

Using 2005 aerial photographs, the distance from each roost to the closest FIPS woodland block and Native Woodland area was calculated along a linear habitat features such as treelines and hedgerows. Information on commuting routes and direction of flight of emerging individual bats were not automatically collected during monitoring surveys. Therefore, this analysis was undertaken as an exercise and assumes that the bats counted would select to feed in the nearest woodland block. Of the 57 roosts monitored, three buildings were located within a FIPS and/or Native Woodland area and therefore travel distance was recorded as zero. For two buildings, there was no commuting route available to the nearest FIPS and/or Native Woodland block but it was noted that areas of scrub and small patches of woodland (<0.5ha) were present within a commuting distance for this species (i.e. 2.5km). The distance was calculated for all remaining roosts (n=52).

The area of FIPS woodlands and Native Woodland Data were mapped. More often than not, the woodland datasets overlapped. The average shortest distance along a commuting corridor (i.e. treeline or hedgerow identified on aerial photographs) from monitored roosts to these woodlands (both datasets combined) was 509.87m (n=55 roosts; but distance ranged from 0m to 1979.75m; Average size of FIPS block = 31.95 ha, range from 0.51ha to 793.53ha). In relation to Native Woodland areas, this type of woodland was more scarce compared to FIPS data and often there was none of the former present within the 2.5km buffer zone of the monitored roost. This was the situation for 26 of the monitored roosts. For an additional four roosts, there were no commuting routes available to this woodland type (Native Woodland data). For the remaining 27 monitored roosts, the average distance to this type of woodland was 1024.59m (n=27 roosts; distance ranged from 18.78m to 2467.87m; Average size of Native Woodland block = 30.7 ha, range from 1.47ha to 232.48ha).

Both FIPS and Native Woodland datasets include areas of woodland/forestry that are greater than 0.5 ha and 1ha respectively. While brown long-eared bats prefer to feed in woodland areas, they will also feed in scrub habitats, along treelines/hedgerows (Russ and Montgomery, 2002) and around individual trees (Entwistle *et al.*, 1996). Therefore, further analysis was undertaken to determine the presence of additional habitats within the five buffer zones (0.5km, 1km, 1.5km, 2km and 2.5km). The selected habitats were treelines, scrub, rivers/canals and lakes/ponds.

Treelines were located within the maximum buffer zone (Buffer 5, 2.5km) for all monitored roosts and, in addition, this habitat type was found within the 0.5km buffer zone for the majority of the roosts monitored (82.5%. See Table 14). Scrub was recorded within 0.5km of 21 monitored roosts (36.7%). A river/canal was located within 2.5km buffer zone of 37 monitored roosts while lakes/ponds were present within 2km of 28 monitored roosts. Overall, the majority of monitored roosts had at least one of these habitat types present within the 0.5km buffer zone (n=51, 89.47%)

Table 14: Habitat types present within the nearest buffer zone around monitored roosts.

Building Types	**Buffer 1**		**Buffer 2**		**Buffer 3**		**Buffer 4**		**Buffer 5**	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Treelines	47	82.5	54	94.7	56	98.2	56	98.2	57	100
Scrub	21	36.8	33	57.9	46	80.7	48	84.2	49	86
River/canal	17	29.8	24	42.1	29	50.9	30	52.6	37	64.9
Lake/pond	8	8.8	15	26.3	20	35.1	25	43.8	28	49.1

Brown Long-eared Bat Habitat and Roosting Requirements

Relatively few building factors showed any significant correlation with average roost count numbers for the 35 monitored roosts selected for this statistical analysis. Some factors were rejected for analysis due to insufficient numbers in each category, e.g. roof type, although this may indicate something about the bats' preferences since the majority of roosts were roofed in natural slate.

In a one way ANOVA, age was found to be close to, but not quite, significant (d.f. 1; F ratio 3.6072; p=0.0892) with older buildings (>100 years, average roost count 30.8) having higher numbers than newer buildings (<100 years, average roost count 21.725).

In a one-way ANOVA the Rural/Urban Edge factor was found to be significantly related to average roost count numbers. There was a significant difference between the two (d.f. 1, 32; F-ratio 7.4629; p=0.0102) with a higher average roost count in Rural sites (2009-2010) 32.999 and the average roost count for Urban Edge locations 19.843. Urban centre roosts were not included due to the low number of roosts monitored in 2009 and 2010 in this category (n=2).

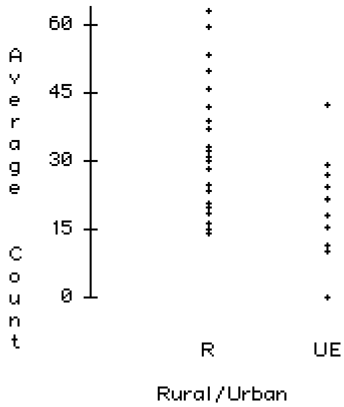

Figure 7: Average counts (2009-2010) for roosts in Rural areas (R) or located at the edge of an urban area (UE).

Principal Components Analysis – 500m Scale

PCA on habitats within 500m radius of the roost showed three components that contributed over 70% of variance (Tables 15 and 16).

Table 15: Eigenvectors contributing to over 70% variance from PCA of habitats at a 500m spatial scale.

Eigenvector	Value	% Variance
E1	13.2	35.6
E2	21.47	16.3
E3	31.22	13.6

Table 16: Component loadings for each factor from PCA analysis of habitats at a 500m spatial scale.

	V1 - Woodland	**V2 – Scrub**	**V3 – Parkland Trees**
Total Cover	**-0.489**	-0.276	-0.032
Treeline Cover	0.246	-0.401	0.144
Hedgerow Cover	0.384	0.154	0.420
Parkland Tree Cover	-0.127	-0.052	**0.831**
Scrub Cover	-0.001	**-0.721**	0.104
FIPS Conifer Mature	-0.393	-0.029	0.143
FIPS Mixed Mature	**-0.403**	-0.016	-0.016
FIPS Other Forest	-0.203	0.284	0.284
FIPS Deciduous Mature	**-0.422**	-0.128	-0.003

When these three components were included in a General Linear Model with average roost count numbers no significant correlation was found.

Principal Components Analysis – 2,500m Scale

PCA on habitats within a 2500m radius of the roost showed two components that contributed almost 80% of variance (Table 17 and 18).

Table 17: Eigenvectors contributing to over 70% variance from PCA of habitats at a 2,500m spatial scale.

Eigenvector	**Value**	**Variance %**
E1	4.348	62.1
E2	1.241	17.7

Table 18: Component loadings for each factor from PCA analysis of habitats at a 2,500m spatial scale.

	V1 - Woodland	V2 – Woodland Edge
Distance to nearest FIPS	0.263	**0.439**
Size of nearest FIPS	-0.106	**-0.507**
Woodland up to 500m	**-0.410**	-0.363
Woodland up to 1000m	**-0.434**	0.345
Woodland up to 1500m	**-0.455**	-0.187
Woodland up to 2000m	**-0.459**	0.139
Woodland up to 2500m	-0.382	**0.495**

These two principal components were included in a General Linear Model to determine whether either have any predictive effect on bat roost counts (Table 19).

Table 19: Results of GLM with principal components 1 & 2 for habitats at a 2,500m spatial scale.

Source	Df	Sums of Squares	Mean Square	F-Ratio	Prob
Const	1	59.6303	59.6303	1264.1	0.0001
Woodland	1	0.0263101	0.0263101	0.55774	0.4616
Woodland edge	1	0.373735	0.373735	7.9227	0.009
Error	27	1.27367	0.00471728		
Total	29	1.67229			

The 'Woodland Edge' factor was shown to be significantly associated with average bat counts. This factor is composed of a negative association with the size of the nearest FIPS woodland block (i.e. larger numbers of bats associated with smaller close woodland blocks), positively associated with the distance to the nearest FIPS woodland (i.e. increased numbers of bats with an increased commuting distance) and positively associated with overall woodland cover within 2.5km.

When this component was included in a further General Linear Model with Rural/Urban Edge category, the rural/urban edge category was found to lose its significance while the Woodland Edge component remained significant, see Table 20.

Table 20: Results of GLM with Woodland Edge Principal Components (habitats at a 2,500m spatial scale) and Rural/Urban Edge category.

Source	**Df**	**Sums of Squares**	**Mean Square**	**F-Ratio**	**Prob**
Const	1	59.665	59.665	2087.4	0.0001
Woodland Edge	1	0.213	0.213	7.436	0.0113
Rural/Urban Edge	1	0.021	0.021	0.734	0.3994
Error	26	0.029			
Total	28	1.150			

Discussion

Survey Effort

Volunteer Teams

The main function of the co-ordinator in relation to volunteer teams is to ensure that the roosts that are assigned and monitored by these teams are suitable and that the volunteers are fully trained in the survey methodology. There is considerable time and travel commitment from the co-ordinator when carrying out counts and preliminary assessments among sites that are widely dispersed around the country. Volunteers recruited for this monitoring scheme need to have some experience in identifying bats using bat detectors. Therefore, there is a small potential pool of volunteers within the country with sufficient expertise available to participate in the scheme. However, teams organised to-date have carried out the counts very successfully, especially when they have been trained in situ by the co-ordinator and a team leader is assigned to organise survey dates, collate survey results and return datasheets to BCIreland. Working closely with local bat groups has also proven to be very effective and should continue for any future monitoring of brown long-eared bats.

It would also be desirable to increase the number of volunteer teams. In 2010, while the co-ordinator undertook monitoring of 23 roosts, volunteer teams completed monitoring surveys of 17 roosts, the majority of which required more than two team members. These roosts could not, therefore, have been surveyed by the co-ordinator alone. The participation of local teams especially in conjunction with local bat groups ensures that there are enough volunteers to survey such roosts adequately.

BCIreland will continue to carry out further volunteer recruitment with an aim to have more than 50% of roosts monitored by volunteer teams and roost owners. Volunteers participating in other monitoring schemes and people who have attended bat detector workshops will be contacted to determine their interest in joining a local team to monitor a roost within their county. This will help ensure that the scheme can continue to be carried out cost effectively.

Roost Owner Participation

The participation of five roost owners in the monitoring scheme has proven to be a very successful way of gathering data. It has provided an opportunity for the roosts' owners to take a greater interest in their bat roosts and to contribute to the conservation of this species. It has also provided BCIreland a valuable opportunity to answer any queries with regards to bats roosting in housing. BCIreland will continue to encourage and assist roost owners with monitoring of their own roosts.

Cost Efficiency

The financial savings of volunteer participation in any monitoring schemes increases its cost effectiveness. However, in comparison to other bat monitoring schemes managed by BCIreland, the savings accrued as a result of volunteer participation may seem considerably lower. The 17 roosts monitored by volunteer teams are all completed by external counts which would amount to an additional 17 field days for the co-ordinator or a total of 34 field days annually. It was estimated that the volunteer effort in this scheme has an approximate value of €7,000. However this sum is calculated at the minimum wage and would be insufficient to employ a team of professional bat workers or ecologists to complete the same body of work, since most of the roosts counted by volunteers require the input of two or more surveyors. Local volunteers surveying local roosts improve the cost effectiveness and sustainability of the scheme.

The co-ordinator currently monitors approximately 50% of the roosts. Many of these roosts can be monitored by internal counts and are surveyed in groups according to locality to reduce costs and travel time. For example, four roosts monitored in County Cavan are all monitored by the co-ordinator. Three of the roosts are counted internally and the remaining one by external count. This means that the annual monitoring for County Cavan can be covered in two days of surveying.

Survey Methodology

Monitoring of wildlife populations is essential to underpin conservation and management. This is the true for bats and the methodology used needs to take into account the particular ecological requirements for the species being monitored (Warren and Witter, 2002). Bat populations tend to be measured using detector surveys in foraging habitats, hibernation roost counts or summer roost counts. For brown long-eared bats, summer roost counts are suitable because they are a roost faithful species and a large number of brown long-eared bat roosts are known in the Republic of

Ireland. The methodology used in this monitoring scheme combines internal counts with external emergence counts and has proven to be suitable means of collecting data cost-effectively. The most suitable method of data collection for each individual roost (i.e. internal or external counts) is determined by the co-ordinator to ensure that volunteer teams can undertake roosts counts with ease. This is essential to ensure that volunteer teams participate from year to year. However, it is important that the same protocol is followed year-on-year to ensure that data collected by different volunteer teams is comparable. Therefore, the methodology presented in this report should be adhered-to strictly by all survey teams. It is also essential that counts are undertaken in suitable weather conditions to ensure that survey results are reliable.

The collection of a minimum of two counts annually provides greater power to detect change over time. It is essential that roosts are surveyed consistently from year to year. Therefore, from the dataset that includes 57 roosts monitored between the years 2007-2010, 40 roosts have been selected for future inclusion in the scheme. This reduced dataset represents roosts that volunteer survey teams can reliably count with ease. The roosts selected also represent small, medium and large sized roosts. It is considered that while large roosts are more stable and easier to find (Warren and Witter, 2002) it is also important to provide a realistic representation of the brown long-eared population, including sub-optimal roosts and locations, and therefore a range of different roost sizes should be counted.

Three survey periods to count roosts are used in this methodology. The reason for this is to register the difference in roost size over the summer period before and after the young are born and flying. However it was noted that some roosts may not have formed by early May and indeed some roosts had already broken up by mid-September. Therefore the duration of Survey Period 1 and Survey Period 3 should be reduced to ensure that counts are undertaken when bats are likely to be present in the roost. Survey Period 2 should stay the same to provide a time when lactating females are present in the roost and therefore internal counts should be avoided during this time.

Geographic Coverage

Roosts were not chosen at random, due to the constraints of locating suitable roosts for surveying. However, the current roost dataset covers a good geographic range throughout the country with the exception of Donegal in the extreme north. Northern Ireland has, to date, not been included in this monitoring scheme. It would, however, be desirable to ensure that the entire geographic spread of the species on the island is covered by the scheme in the coming years so BCIreland proposes to seek funding from the NIEA to establish the scheme in the North. However there are still some gaps in the geographic coverage in the Republic of Ireland which should be addressed by any future monitoring programme.

Potential Roosts for Investigation

Currently there are gaps in the location of monitored roosts, principally Counties Louth, Westmeath, Donegal, Carlow and Kerry. However, the 40 roosts (of the original 57 roosts monitored) recommended for future monitoring only covers a geographical spread of 15 counties. A search of the BCIreland database shows an additional 10 roosts with records of eight or more individuals are potentially available (Counties Clare, Kerry, Kilkenny, Longford, Roscommon, Wexford and Wicklow). These records were collected within the last 10 years and, if checked, may be found to be suitable for inclusion in a future monitoring scheme. NPWS regional staff have also provided information about another seven roosts (Counties Galway, Wexford, Waterford and Offaly) which brings to 17 the number of additional roosts potentially available for future monitoring. While it is the aim of the scheme for 40 roosts to be monitored annually, it would be considered prudent to aim to have up to 50 roosts monitored annually in case, due to unforeseen circumstances, some roosts are not counted twice. Gathering data on more than 40 roosts should ensure that the Power of the monitoring remains statistically robust.

In addition, there are currently 44 proposed Natural Heritage Areas (pNHAs) for bats, seven of which are selected for brown long-eared bats. Only two of these roosts (Site Code 000244 Clonfert Cathedral and Site Code 000250 Cloughballymore House) are currently part of the monitoring scheme while the remaining five (Site Codes 000567, 002063, 002064, 002066 and 002080) were not investigated or surveyed by this scheme. These sites are located in Counties Offaly, Tipperary and Galway. The additional five pNHA sites should be investigated in conjunction with regional NPWS staff to determine whether they are suitable for monitoring as part of this scheme. Also, to include all seven pNHAs for this species in the monitoring scheme would provide much-needed data for the sites and may assist in future conservation measures.

However, this still leaves Counties Louth, Westmeath, Donegal and Carlow without coverage which would require investigation to ensure that there is national coverage and therefore a good geographical spread of monitored brown long-eared roosts.

Buildings Surveyed

The majority of roosts are located in churches and large buildings or mansions. This may be expected given the long-eared bat's preference for roosting in attics with large roof spaces (Swift, 1998). Churches are often particularly suitable for a study such as this since it can be easier to gain permission for access to these buildings than private dwelling houses. Most of the churches surveyed are Church of Ireland buildings as may be expected, since these structures are regularly used by brown long-eared bats. In a survey of Church of Ireland Churches in the late 1990's 67% of those checked were found have evidence of roosting brown long-eared bats (Roche, 1998). In addition, 80.7% of the buildings surveyed in this monitoring scheme are constructed of stone, 82.5% have natural slate roofs and all are located within 2.5km of woodland.

The roosts that have proven too difficult to survey for inclusion in the monitoring scheme are mainly buildings with many exits, particularly large mansion houses. Many additional roosts that have been checked were found to be unsuitable because few or no brown long-eared bats were present. Possible reasons why no bats or too few bats may be present in some roosts are:

- little or no suitable surrounding habitat
- no continuous natural linear features to foraging habitats
- aesthetic lighting in the surroundings rendered the building unsuitable for brown long-eared bats

Roost Loss from Dataset

The potential problem of roost abandonment has been discussed in the Introduction; it is possible that false declines may be picked up or true declines may be missed when roosts are abandoned. While several sites were removed from the monitoring dataset because of declines in bat numbers between 2007 and 2010, introduction of external building lights and hedgerow removal were considered responsible for abandonment of some roosts and the bats themselves are presumed to be present elsewhere in the local area. Reporting of roost abandonment to the NPWS, particularly in cases where new lighting or habitat loss is a direct contributor, will be a priority for BCIreland to help ensure continued protection of roosts. Follow up surveys may be appropriate in such cases, in liaison with local wildlife rangers, to determine the new location of colonies such as these and to confirm that the bats are still present.

The current dataset shows stable or slightly increasing trends which is an encouraging outcome from the first few years of the survey. Trends from the BCT NBMP also indicated increasing population figures from the first few years of the survey followed by a slight decline from 2007-

2009. This is also encouraging and suggests that trends from data collected by the BCIreland scheme are being derived independently of mobility between roosts.

Monitoring Dataset and Trend Analysis

The number of bats counted at the roosts included in the monitoring dataset has ranged from 0 to 98 individuals. The majority of roosts are counted during evening emergence with a small number using a combination of evening emergence and interior counts at suitable times. As may be expected, average counts are higher for the third survey in the season when young are volant.

From a Generalised Linear Mixed Model (GLMM) with a Poisson error distribution fitted to the 2007-2010 dataset, various parameters were checked to determine whether they impacted on the counts. The only variable of significance was internal/external counts. External counts tend to be higher than internal ones but the internal ones tend to be more variable. No other variables were found to be significant. This suggests that external counts may produce more reliable results for inclusion in the trend analysis. However, for some areas, considerable cost and time efficiencies can be made by carrying out several internal counts in one day.

So far the long-eared monitoring dataset for Ireland appears to indicate a slightly increasing trend although the survey is still at a very early stage so this could easily change in the coming years. The trend from long-eared bat roost counts in the UK indicated declines from the 2007-2009 period (Anon, 2009).

Power Analysis

Results from Power Analysis of the dataset are very encouraging. With just twenty roosts counted twice annually a red alert decline can be detected within 10 years and an amber alert decline can be detected inside of 20. These results are somewhat similar to those for soprano pipistrelles (11 and 22 years for red and amber alerts, respectively) derived from the car-based bat monitoring scheme (Roche *et al.*, 2009). With 50 brown long-eared bat roosts counted twice annually the results from power analysis roughly match the number of years of monitoring required to detect red and amber alert declines in common pipistrelles also derived from car-based bat monitoring data, eight and 13 respectively (Roche *et al.*, 2009). Increases take a little longer to detect accurately. The current brown long-eared bat roost monitoring scheme appears, therefore, to result in robust data for determining population trends in long-eared bats in Ireland. Missing values do result in a loss of power in the dataset and while some of these are inevitable it will be important to ensure that counts at core sites are repeatedly carried out. This may require renewed recruitment of volunteers in areas where original surveyors are no longer available. For this reason it is important for BCIreland to keep in close communication with volunteers and to encourage those who are unable to carry out counts to inform BCIreland well in advance of the field season. Thus, the current aim, to survey 30 to 50 roosts per annum (minimum two counts per year), is probably quite reasonable in optimising surveyor effort but still deriving robust results.

Effects of Reducing the Survey Protocol

A reduced survey protocol was also investigated. Counting a minimum of 30 roosts once per year increases the number of years of detecting red alerts from 13.3 years under the current recommendations to 19 years. In addition, counting 30 roosts once every two or three years further reduces the power of detecting red alerts. Considering the amount of data gathered to-date and finding 40 roosts suitable for monitoring it would be important to complete monitoring annually to ensure that data is being gathered at least on an annual basis. This could then be supported by undertaking the recommended monitoring protocol of counting 40 roosts twice in the 3rd year of the cycle if funding was available. To ensure that reliable data is collated from a reduced monitoring protocol, roost counts should be undertaken in the survey period of mid-June to end-July as counts from this period have provided more stable data compared to the other survey periods (i.e. May to mid-June and August to mid-September).

Automated Roost Counts using AnaBat

At the two sites where the AnaBat was deployed to carry out roost counts simultaneously with a surveyor the AnaBat recorded significantly fewer bats than the human observer. The differenced values varied between one site where 7.7% fewer bats were observed, compared with another where on average 13.75% fewer bats were counted on each occasion. This suggests that, while the AnaBat may be a useful tool for carrying out surveys where there is a lack of surveyors available, more work may be required to determine whether a multiplication factor, specific to each site, could be applied to AnaBat count data to render it compatible with observer count data prior to inclusion in the overall dataset.

GIS Analysis

Percentage of Woodland & Forestry Habitat

GIS analysis was undertaken for all 57 roosts initially and these results were briefly summarised. However, further analysis was undertaken using a reduced dataset of 35 roosts that were monitored consistently in 2009 and 2010 to examine the importance of the proximity of roosts to woodlands and the commuting distance to such habitats from the roosts.

Brown long-eared bats are described as a woodland foraging species (Swift, 1998) and numerous studies over the years have confirmed their dependence on woodlands, deciduous ones in particular, for foraging (e.g. Entwistle *et al,* 1996; Vaughan *et al,* 1997; Russ and Montgomery, 2002; Hill and Greenaway, 2008). In Ireland, however, Shiel *et al*. (1991) showed from analysis of droppings collected in roosts in the west of Ireland that over 18% of their diet was composed of yellow dung flies, which suggests a pastoral component in its foraging strategy here. It is considered that availability of foraging habitats affects the size of the bat population (Boyd and Stebbings, 1989). The present GIS analysis of the 57 monitored roost dataset showed that the majority of roosts had woodland within 0.5km of their locations and that all roosts had blocks of woodland within 2.5km. Further detailed breakdown of woodland types within 500m of each roost was also carried out for a subset of the monitored roosts.

Proximity to Woodland & Forestry Habitat: Commuting Routes

The slow flight of brown long-eared bats is considered by Entwistle *et al.* (1996) to limit how far this species can travel to favoured feeding sites. Brown long-eared bats are known to follow hedgerows, treelines and riparian habitats to preferred feeding sites potentially resulting in a much greater distance being travelled compared to the direct route. As a consequence, the commuting distance from roosting sites to potential foraging habitats could be more important than the presence of woodland within a selected distance or buffer area. Entwistle *et al.* (1996) found that brown long-eared bats can travel up to 2.8km from the roosts, but the majority of foraging time tends to be within 0.5km to 1.5km from roosts. For this study the commuting distances (rather than the direct line distance) from roost locations (57 monitored roosts dataset) to nearest woodland block were determined. The average distance was approximately 0.5km, although some roost sites were located more than 1.5km from the nearest FIPS woodlands and for the majority or roosts, a greater distance was required to travel to native woodlands listed under the Native Woodland Inventory.

Brown Long-eared Bat Habitat and Roosting Requirements

Using the data collated above and other parameters collected about the structure of the roosts for the reduced dataset of 35 roosts, further analysis was undertaken. Building age may be important with higher numbers in older buildings (>100years) than in more modern buildings (<100years), although this relationship was not quite significant. The location of a roost in either a rural or urban edge area was shown to be an important factor influencing average roost counts, with higher counts recorded from sites in rural areas. The association between roost counts and rural vs urban edge habitats may be expected. Jones *et al.* (1996) found a negative association between brown long-eared bat roosts and urbanization. Street lighting may be a factor in causing a decline in long-eared bats in urban areas, although habitat loss is also likely to have a part to play.

Principal components analysis of habitat variables was carried out at two spatial scales, one within 500m of the roosts using detailed information on cover of woodland types, small woodland blocks, treelines and hedgerows. From this analysis, no signification association was found with the principal components and bat abundance in roosts at the 500m scale. However, at a 2,500m scale, PCA followed by application of a General Linear Model indicated that a woodland edge component was significantly associated with bat roost count numbers. Higher numbers of bats were counter-intuitively associated with further commuting distances, smaller nearby woodland block sizes, but also, larger overall FIPS woodland area within 2.5km. It is possible that this result may have arisen due to chance, since the dataset is relatively small. Or it may indicate the importance of woodland edges for this species in Ireland where it has been shown to include a pastoral component in its diet. With roost location (in urban or rural context) included in a General Linear Model with the 'woodland edge' principal component, the roost location factor was found to lose its significance while the woodland edge component remained significant. This may suggest that habitat loss from urban areas is the main reason for lower numbers of bats at these sites, rather than an avoidance of urban areas per se.

A more thorough study of the species using radiotelemetry may be particularly useful in determining the species' requirements in Ireland.

Recommendations

Brown long-eared roost monitoring should continue with 2-3 counts completed annually in a minimum of 40 roosts. Should additional or replacement roosts be required the 5 pNHAs listed for brown long-eared bats and not included so far should be considered as a priority.

Dates for survey periods should be changed to the following: Survey 1: 16th May to 15th June; Survey 2: 16th June to 31st July & Survey Period 3: 1st August to 30th August.

In view of the current economic climate a reduced monitoring protocol may be required. BCIreland should tally costing strategies for a variety of scenarios, such as counting 30 roosts annually during mid-June to the end-July period but with a minimum of 40 roosts counted twice every three years.

Volunteer recruitment should continue with the aim of having more than 50% of roosts monitored by volunteers / roost owners. Volunteers participating in other monitoring schemes and people who have attended bat detector workshops will be contacted to determine their interest in participating. This will help ensure that the scheme can continue sustainably and cost effectively.

Roost owners should be encouraged and assisted to undertake monitoring of their own roosts.

Close communication with volunteers should continue and volunteers who are unable to carry out counts should be encouraged to inform the scheme co-ordinator well in advance of the field season.

Further AnaBat counts should be carried out to determine whether this technology can be deployed at roosts to carry out counts and the data included in the overall trend dataset.

BCIreland should seek funding from the NIEA to establish the scheme in the North with the aim of dividing costs and providing a greater geographic spread. In so doing it will provide a more robust dataset to detect Red and Amber Alerts.

Further analysis of roost types, location and habitats within buffer zones around roosts should be undertaken. Detailed field work on habitat usage within buffer zones should be conducted for a small number of monitored roosts. Such information will be valuable for the conservation of brown long-eared roosts and aid the location of other suitable brown long-eared roosts.

BCIreland should enquire into the design of a brown long-eared bat survey Smart Phone App to assist surveying teams and roost owners.

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Appendix 1

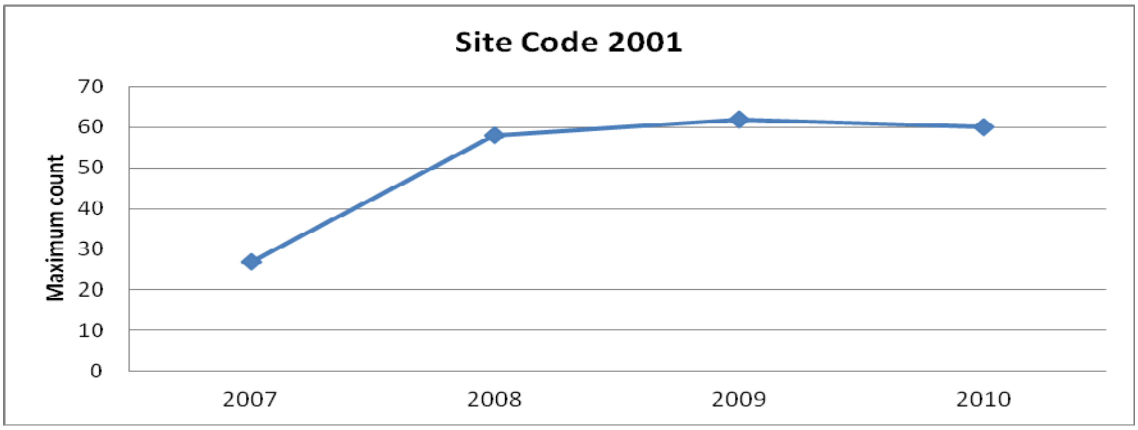
Table 1: Location of roosts monitored during 2007 to 2010

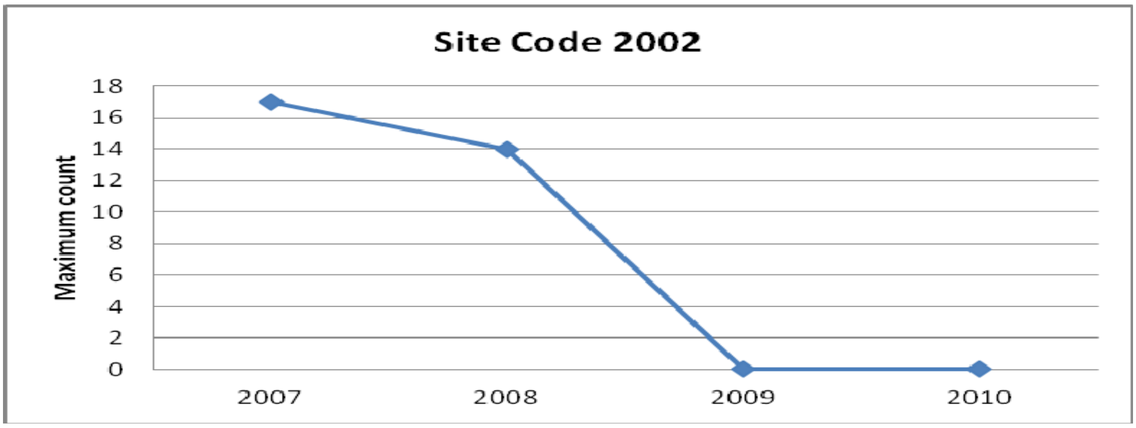
Code	Location: County	Eastings	Northings	Building
2001	Kilmore, County Cavan	238480	303513	Church
2002	Ballivor, County Meath	268000	264000	House
2003	Glendalough, County Wicklow	312300	196700	Castle
2004	Millstreet, County Cork	133707	97662	Church
2005	Timoleague, County Cork	147200	43800	Large building/mansion
2006	Currabinny, County Cork	179854	61938	Large building/mansion
2007	Millstreet, County Cork	127900	90400	Other
2009	Glenealy, County Wicklow	324600	192300	Church
2010	Balbriggan, County Dublin	321888	261214	Large building/mansion
2011	Headford, County Galway	130900	248100	House
2012	Gort, County Galway	143800	207900	Castle
2013	Ennisnage, County Kilkenny	252496	148995	Church
2014	Clone, County Wexford	300519	143249	Church
2016	Rathkeale, County Limerick	139670	139242	Large building/mansion
2017	Hazelwood, County Sligo	171000	335000	Large building/mansion
2018	Castleknock, County Dublin	308000	236000	Large building/mansion
2019	Ballyconnell, County Cavan	227100	318800	Church
2020	Ballincollig, County Cork	151800	69000	Agricultural building
2021	Birr, County Offaly	206500	194300	Large building/mansion
2022	Pearson's Bridge, County Cork	102174	55591	House
2023	Glengarrif, County Cork	91023	57423	Large building/mansion
2024	Bantry, County Cork	99887	48189	Church
2027	Dunmanway, County Cork	123000	52000	House
2029	Ballinkeel, County Wexford	302650	133650	Agricultural building
2031	Ballygar, County Galway	178000	252000	Large building/mansion
2034	Birr, County Offaly	206057	207172	Large building/mansion
2035	Inagh, County Clare	120830	181244	Church
2038	Portlaw, County Waterford	246500	115300	Church
2039	Kilmeadan, County Waterford	251600	110900	Church
2042	Kilmore, County Cavan	238500	303800	Large building/mansion
2045	Emo, County Laois	253700	206600	Large building/mansion
2047	Borris-in-Ossory, County Laois	224000	187000	Large building/mansion
2048	Timahoe, County Laois	253600	190200	Church
2055	Kells, County Kilkenny	249928	142667	Large building/mansion
2060	Hazelwood, County Sligo	172000	335000	Agricultural building
2062	Clonfert, County Galway	196150	221150	Church
2063	Ballycormack, County Longfrod	211600	271000	Church
2064	Horetown, County Waterford	287517	119690	Church
2065	Swanlinbar, County Cavan	219400	327200	Church
2066	Baileboro, County Cavan	261700	301400	Church
2067	Riverstown, County Sligo	174117	319996	Church

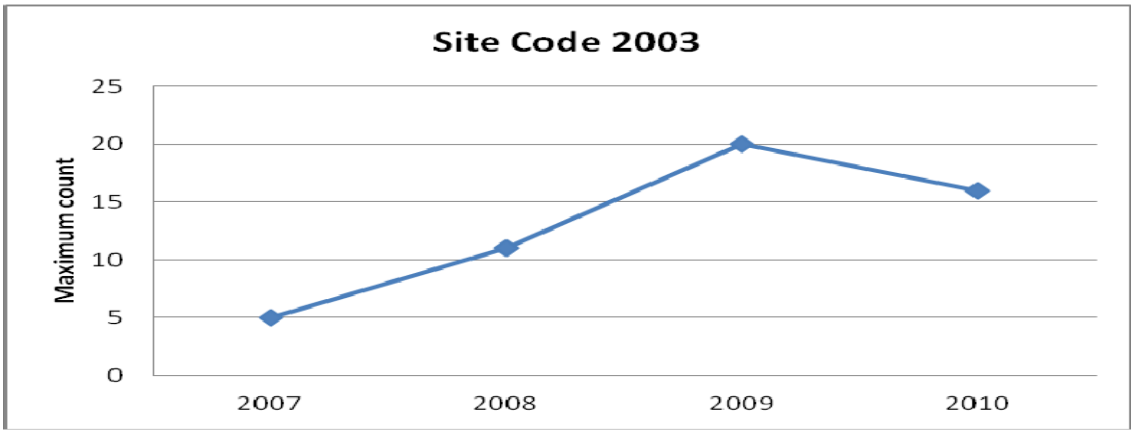
2072	Crohan, County Tipperary	227830	145640	Church
2081	Kinlough, County Leitrim	181500	355500	House
2082	County Roscommon	194300	291300	Agricultural building
2083	Beltra, County Sligo	159949	330379	Church
2086	Peterswell, County Galway	150700	206900	Church
2088	Ballinfad, County Sligo	178250	308650	Large building/mansion
2089	Drimoleague, County Cork	112700	46200	Church
2090	Screen, County Sligo	152400	332600	Church
2091	Tobercurry, County Sligo	152000	311000	Large building/mansion
2092	Donnameade, County Kildare	283600	233200	Church
2100	Cloughballymore, County Galway	139775	214075	Large building/mansion
2101	Belclare, County Mayo	119000	282200	Large building/mansion
2102	Kinlough, County Leitrim	181450	355600	House
2116	Riverstown, County Sligo	176293	316392	House
2117	Kilcolgan, County Galway	144950	222050	Large building/mansion
2118	Donaghmoyne, County Monaghan	285750	306750	Church

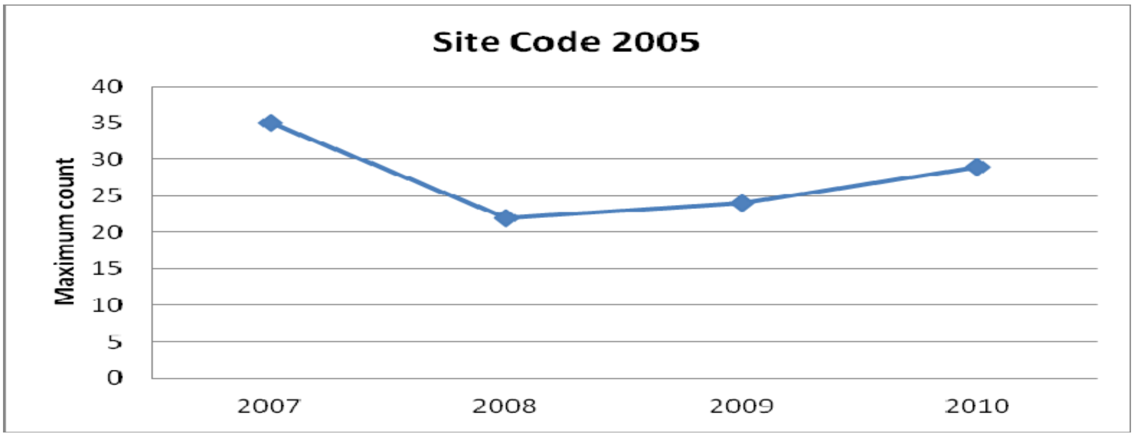
Appendix 2

Plots of maximum counts per annum for all ten roosts with four years of count data.





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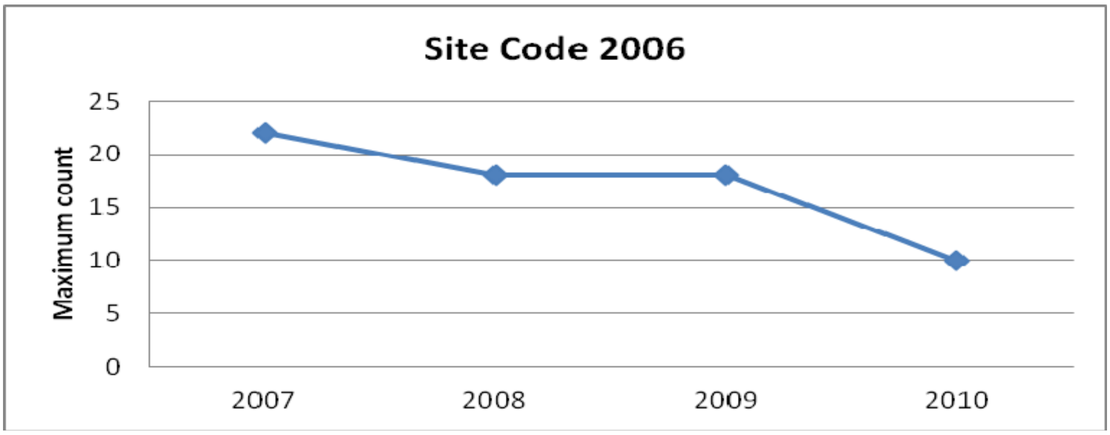
35
30
25
20
15
10
5
0
2007
2008
2009
2010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Maximum count
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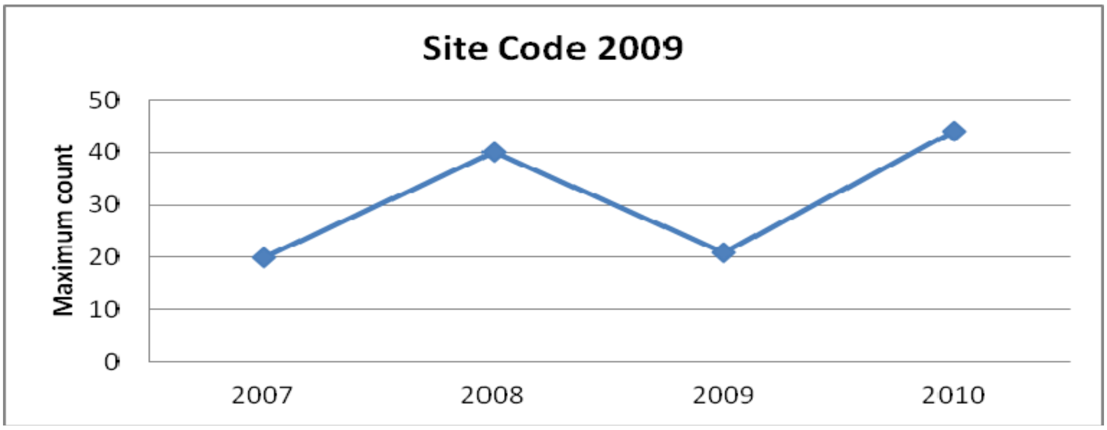
20
15
10
5
0
2007
2008
2009
2010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Maximum count
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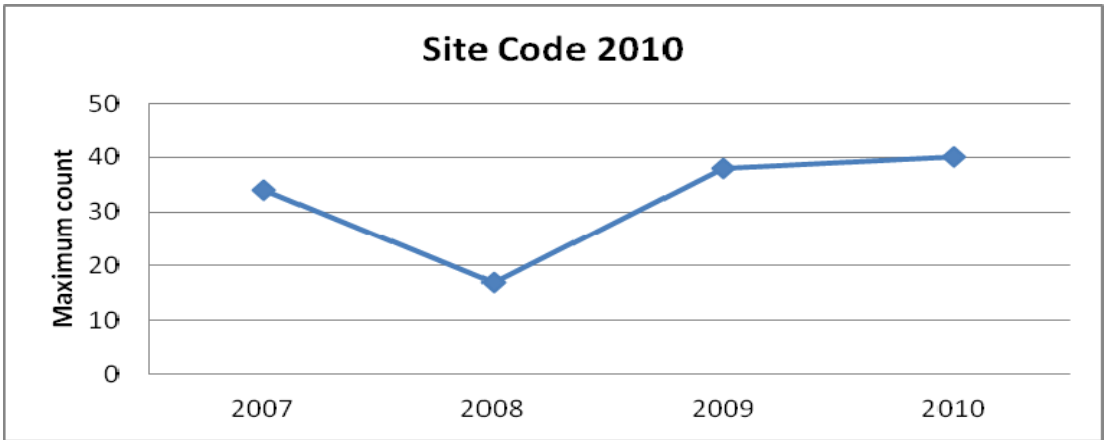
40
30
20
10
0
2007
2008
2009
2010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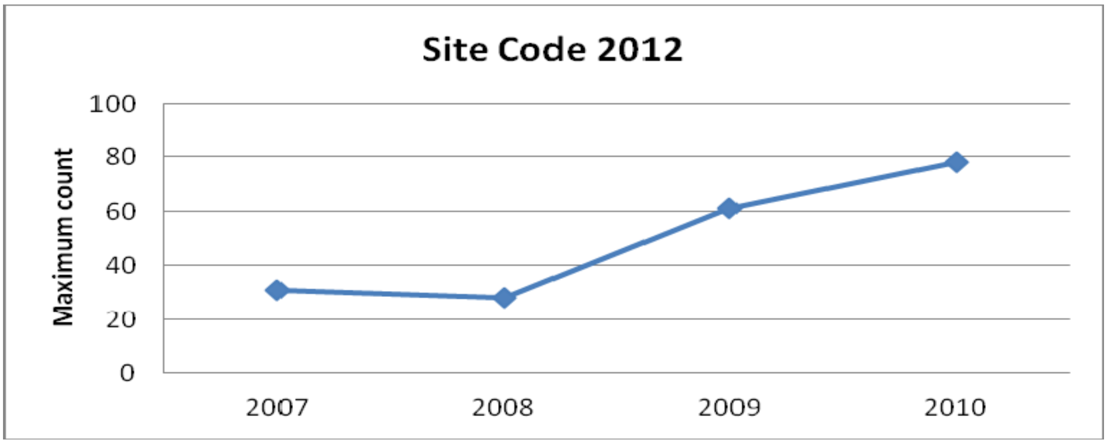
2007
2008
2009
2010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60
40
20
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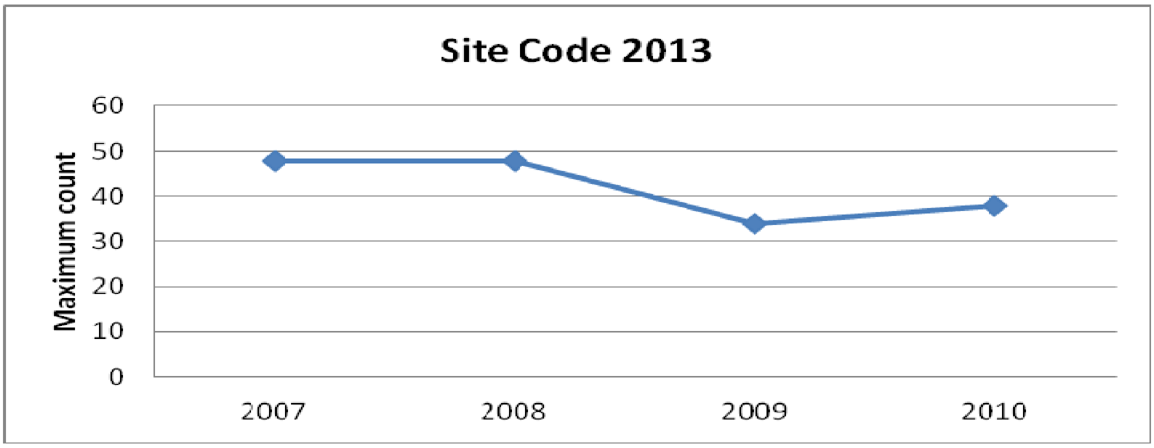
2007
2008
2009
2010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30
20
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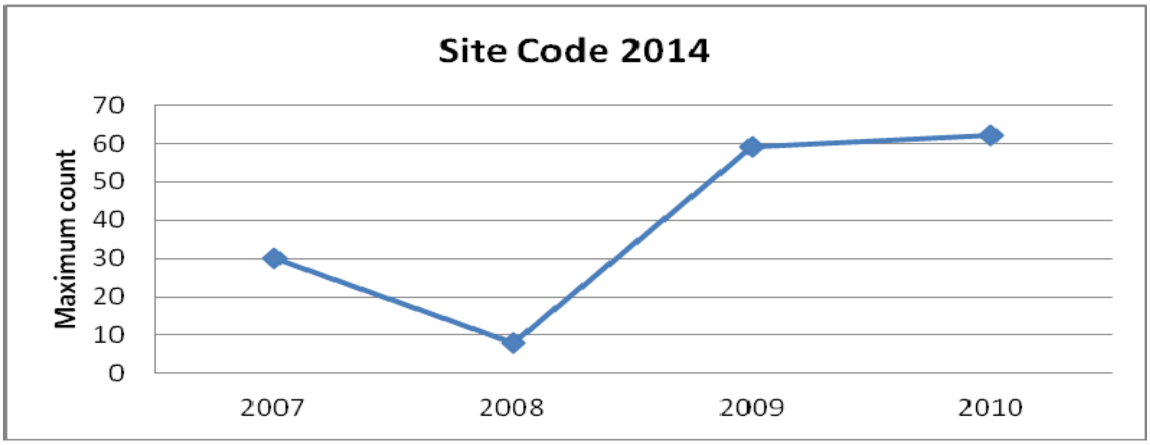
2007
2008
2009
2010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60
50
40
30
20
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0
2007
2008
2009
2010