ISSN 1393 – 6670

Lesser Horseshoe Bat: population trends and status of its roosting resource

Irish Wildlife Manuals No. 85

An Roinn
Ealaíon, Oidhreachta agus Gaeltachta
Department of
Arts, Heritage and the Gaeltacht

Lesser Horseshoe Bat: population trends and status of its roosting resource

Niamh Roche, Tina Aughney and Steve Langton

Bat Conservation Ireland

Citation:

Roche, N., Aughney T. and Langton S. (2015) Lesser horseshoe bat: population trends and status of its roosting resource. *Irish Wildlife Manuals*, No. 85. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Ireland.

Keywords: Lesser horseshoe bat, population trend, monitoring, site assessment, power analysis

Cover photos: Lesser horseshoe roosts © Niamh Roche and David Lyons

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

Irish Wildlife Manuals Series Editors: F. Marnell & R. Jeffrey

ISSN 1393 – 6670

Contents

Executive Summary

The lesser horseshoe bat monitoring scheme is carried out every summer and winter across the range for the species in Ireland. The scheme involves counts of individual bats roosting in summer and hibernating bats in winter. Selected winter sites were counted from 1986 while summer site counts were initiated in 1992. For surveys in both seasons, sample sizes were low in the early years of the survey. All available lesser horseshoe bat data was originally reviewed and collated in 2002-2003 by Conor Kelleher and subsequently entered into an MS Access database by Naomi Kingston of the NPWS in the mid-2000s. This database was handed over to Bat Conservation Ireland in November 2013. The database contained 3,200 count records in November 2013. Following further data collection, querying of records and cleaning of data the number of records on the database, in April 2015, now stands at 4,132.

For summer 2013, 147 discrete count records were provided by 22 surveyors. A maximum of 6,614 bats were counted at the 84 sites within the official survey period (May 23rd to July 7th) while 8,727 bats were counted from 102 sites in 2014 in the same time period. For winter 2014, 103 discrete records were provided from 100 sites surveyed by 34 individuals. A total of 5,569 bats were counted at these 100 sites while 6,508 bats were counted from 105 sites in winter 2015.

For both summer and winter counts, trend analyses are carried out using day number as a covariate and GAM smoothing. Summer counts at 192 sites were included in trend analysis, which includes some sites that were counted outside the recommended survey period. For winter trends count data from 129 sites were included in analysis. Sites that have never had any record of live bats or have had less than two years of survey data are not included in trend analysis, hence the lower number of winter sites included in trend analysis than have actually been surveyed. The winter trend time series runs from 1986 to 2015, while the summer trend time series stretches from 1992 to 2014. For both seasons' counts increases were evident in the 1990s and early 2000s that levelled off in the late 2000s. Winter counts showed evidence of an increasing trend since around 2012 while summer sites just have more recently begun increasing again.

Power analysis was carried out using simulated data that are designed to have similar means and variances to the real data. For winter counts a reduced scenario of counting at 30 core sites annually and counting at additional sites every three years was used and, as a consequence, the power of the data to detect amber alert declines would be considerably reduced. Simulations suggest that it would take 11.6 years to detect a red alert decline and 22.5 years to detect an amber alert decline if 75 sites were counted annually in winter. With the reduced survey protocol it would take 13 years for a red alert but 28 years for an amber alert decline. For annual

summer counts it would take 8.6 and 14.8 years to detect red and amber alerts, respectively but 9.9 and 18.3 for this reduced survey plan.

A review of the status of monitored sites revealed that 'bad' sites, e.g. sites that have deteriorated to a point where they may soon be abandoned by bats, are widely scattered across the range for the species with no real clusters of poor sites. Analysis showed that declines in poor sites tend to correspond to increases in other nearby sites which suggests a degree of mobility among the population. Regression slopes were used to determine the extent of change that has occurred at each site over the past five years. A region-based review of these data was then carried out and recommendations were made for how to tackle potential problems.

Acknowledgements

Bat Conservation Ireland would like to thank the team of hard working and dedicated surveyors who carry out lesser horseshoe bat surveys. These include:

Alan Daly
Brendan O'Shea
Cameron Clotworthy
Clare Heardman
Damien Kelly
David Lyons
Declan O'Donnell
Denis Downey
Danny O'Keeffe
E. McCartan
Elaine Keegan
Emma Glanville
Eoin McGreal
Fionnuala Lyons
Frank McMahon
Ger O'Donnell
Helen Carty
Irene O Brien
Jacinta Murphy
Jim O'Toole
John Higgins
John Joe O'Connell
Karsten Krieger
Kate McAney
Kathryn Freeman
Liam Lenihan
Máire O'Connell
Marcella McDonnell
Maurice McDonnell
Michael O'Sullivan
Nora Coffey
Paschal Dower
Patrick Graham
Paul Murphy
Penny Bartlett
Raymond Stephens
Rebecca Teesdale
Shane Casey
Sinead Biggane
Stefan Jones
Tim Burkitt
Tina Aughney

We would also like to express our gratitude to roost owners for allowing access. Thank you to John Higgins and Ger O'Donnell for facilitating the December 2013 meeting in Clonbur and Frank McMahon for the 2014 meeting in Killarney. Thanks to staff at Met Éireann for providing weather datasets.

In addition, sincere thanks to staff at NPWS: Ferdia Marnell, Ed Wymer, Deirdre Lynn and former NPWS staff member Naomi Kingston.

1. Introduction

The lesser horseshoe bat (*Rhinolophus hipposideros*) is mainly found in counties on Ireland's western seaboard Mayo, Galway, Clare, Limerick, Kerry and Cork although its strongholds are found in Kerry/west Cork and in Clare. The lesser horseshoe bat is Ireland's only Annex II-listed bat species (as per EU Habitats Directive [92/43/EU]). This means that its population requires special protection measures and designation of Special Areas of Conservation within the Natura 2000 network. These designations are usually roost or hibernacula-centred and focus on large roosting sites for the species, usually with >50 individuals in winter or >100 individuals in summer.

BCIreland carried out analysis of the Lesser Horseshoe Bat database in 2012, see Roche *et al.* (2012). Initial results were encouraging and indicated that the species has increased for much of the duration of its monitoring scheme. However, concerns have been expressed about the state of deterioration of many of its roosting sites. The present report details population trends for the species to winter 2015, as well as results from power analysis, analysis of weather data and a review of site assessments across the range for the species.

2. Methods

2.1. Surveys

Surveyors were trained in survey methodology prior to BCIreland's involvement in the scheme. For winter sites one count is carried out that should be conducted at each roost between January 1st and February 28th. Site visits should be preceded by 2-4 days of 'cold' weather, ideally 3-4 days of frosty weather. All bats seen are counted using a standardised search of the roost site. If lamps are necessary, a red filter is recommended.

In summer two counts are requested, preferably separated by one week, between May 23rd and July 7th. Counts should not be made in poor weather conditions. If conditions deteriorate during a count, it should be abandoned. Prevailing weather conditions are recorded.

Surveyors are requested to familiarise themselves with the roost site beforehand, in particular the number of exits and the pattern(s) of emergence. The required number of observers should be available to cover all exits and place them so that the bats can be counted accurately without their dispersal being impeded. Observers should be clearly briefed and in place at sunset and should remain until 10 minutes after the last bat emerges.

Use a bat detector tuned to 110 kHz to distinguish horseshoes from other species. Only those bats seen emerging and echolocating at this frequency should be counted. Use a hand-held tally counter to record bats returning to the roost. Once the period of emergence is over, subtract the figure on the counter from the total number counted to give the actual number of bats present.

Surveyors are provided with equipment needed for the survey by the NPWS or Vincent Wildlife Trust (VWT).

Each year survey teams complete surveys of specific sites within their district.

A field meeting with regional NPWS and VWT staff who carry out the lesser horseshoe bat counts was held at Clonbur, Co. Galway in December 2013 and at Killarney in December 2014. During the 2013 meeting the issue of facilitating recording of activities at roost sites was discussed with regional staff. Following these discussions, revisions were made to the Excel recording sheet for each district, these were sent to relevant District Conservation Officers (DCOs) in December 2013 and further modifications were made in early January 2014.

Data was provided in Excel spreadsheets by NPWS regional staff for a number of survey seasons. These data were cleaned, queried (where necessary) and imported to the database using the Excel to Access Import function in Access.

2.2. Data Management

In November 2013, the MS Access Database LHB_April_2012 was provided to Dr Niamh Roche of Bat Conservation Ireland by Dr Ferdia Marnell, NPWS. This database contained 3,200 discrete bat records. Additional data products provided by NPWS were

- a DVD with raw data from 2002-2003
- hard copy 6 " maps with lesser horseshoe bat roost locations that were mapped by Mr. Conor Kelleher as part of a similar project in 2002-2003.

Initial tasks to manage the database involved adding two new data fields to the Count_details table. These data fields were entitled

- CorrectDate
- CorrectedNumberCounted.

The aim of these two columns was to carry across valid count and date data where the current columns list text instead of integers (e.g. '>10' or 'approx. 20') or unspecific dates (e.g. 'In the past', or 'Summer 1995') that cannot be included in trend analysis. Data was cut and pasted from existing Count and Date columns and changed in following manner:

- Dates with no month and/or year were deleted. Dates with month and year (but no day) were changed to 15th of the month. One record with 30/02/1994 was changed to 20/02/1994.

- Count data that included text characters e.g. < or + had text removed and minimum number in range was selected for inclusion in CorrectNumberCounted. Count data for other bat species was deleted from CorrectNumberCounted so that it solely presents data for lesser horseshoe bats. Counts for Site 058, Poulnadatig and Poulnagollour, were totalled where both were available but deleted from CorrectNumberCounted where just count for one was available

Further modifications were made to site names, grid references and other details as discussed with NPWS regional staff. Full details of modifications to records and sites are recorded in the document

- LHBdatabase_recordofchanges.doc.

2.3. Site Assessments

In order to determine the state of the current roosting resource for the species in both summer and winter, all surveyors were asked to assess their sites. Surveyors were asked to apply a traffic light system to their sites roughly based on EU guidelines for species assessments, but in this case the assessment was applied to each site separately.

The assessment matrix shown in Table 1 was provided as a framework for assessing each site.

Table 1: LHB Site Assessment Matrix. A site is assessed as Favourable where all factors are considered favourable, Amber where Favourable and one or more Unfavourable – Inadequate factors are chosen and Unfavourable - Bad where one or more Unfavourable Bad factors are highlighted.

	Favourable	**Unfavourable – Inadequate**	**Unfavourable – Bad**	**UNKNOWN**
Structure & Functioning of Site (building)	Stable	Deterioration (preliminary)	Deterioration (advanced)	
Structure & Functioning of Site (underground)	Stable	e.g. high flooding occurs but has not yet been known to impact bats, or dumping at entrance but has not impacted bats	e.g. flooding has caused reduction in numbers; dumping has blocked entrance	
Surrounding Habitats	Stable	Woodland, scrub &/or linear features within 500m radius – loss of up to 25%.	Woodland, scrub &/or linear features within 500m radius – loss of >25%.	
Numbers	Stable or increasing	Evidence for decrease (up to 25%) not attributable to random fluctuation. Exact cause may be unknown.	Evidence of large decrease (>25%) not attributable to random fluctuation. Exact cause may be unknown.	
Additional threats	None known	Other threats/impacts not specified above that are considered to render site very vulnerable to disturbance or loss	Other threats/impacts that have already caused losses at site	
Future Prospects	Excellent or good	Any set of conditions between favourable and unfavourable-inadequate	Severe impact from threats/habitat and/or roost rapidly declining	

In order to process the information submitted by surveyors a table entitled Site_Assessments was added to the lesser horseshoe bat database. The data included in this table are:

- Bat Site Code

- Site Assessment (Favourable, Unfavourable – Inadequate, Unfavourable – Bad, Unknown)
- Assessed By
- Date of Assessment
- Comments

The Bat Site Code links these site assessment data to other information in the database. It is not anticipated that site assessments will be carried out every year. However, a second assessment prior to Article 17 reporting in 2019 may be useful.

2.4. Weather Data

Weather data from 1993 onwards was kindly supplied by Met Éireann in the form of ascii files with daily temperature (max and min), monthly temperature, daily rainfall, monthly raindays and rainfall, and daily windspeed among the data fields provided. BCIreland then collated the weather data to a purpose-built Access database for use in all monitoring schemes.

2.5. Statistical Analysis

For overall yearly trends, a Generalised Linear Model (GLM) with a Poisson error distribution (see Glossary) was applied to the data. Confidence intervals are generated by bootstrapping (Fewster *et al.* 2000) as used in Generalised Additive Model (GAM) analysis.

Generalised Additive Models (GAMs) have been fitted to the annual means to give a visual impression of the trend over time. Curved trend lines have been applied to the data with 6 degrees of freedom.

2.5.1. Power Analysis

Simulations are based on the variance components from a REML model of bat counts per survey, transformed using normal scores (see for example Armitage & 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 = 0.025 (equivalent to P = 0.05 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

Results should be treated with caution as they are dependent on many assumptions, some of which will only be approximately correct. In particular, the simulations assume that the same trend applies across all habitats, and more sites will be needed in the situation where the extent of change varies geographically or between different habitats. It is also assumed that all surveys are successfully completed; missing surveys will increase the number of sites needed to achieve the specified level of power.

2.5.2. Statistical Analysis of Met Data

Even with population trend models spanning two decades or more, demonstrating any formal statistical relationship with climate is problematic because the number of potential explanatory variables is so large. We considered formal testing where we identified a plausible relationship, either from graphs comparing trends and monthly met data, or from expert knowledge of how the species may be affected by the weather. An example of this is the finding by Ransome and McOwat (1994) that spring temperatures have a positive correlation with birth timing and population size.

Data from met stations in the west and south-west of Ireland were used in the analysis. These were defined as having an easting less than 170 and northing less than 300. This area encloses all the lesser horseshoe sites counted, see Figure 1.

Figure 1: Locations of met stations used in the analysis. This map shows stations that contributed temperature data in at least one year.

2.5.3. Analysis of Site Assessments

Simple Kruskall Wallis tests were carried out to compare counts between years in sites of different assessment categories. Comparisons between two years like these are, however, subject to annual fluctuations as well as missing values. Hence a better approach statistically is to calculate regression slopes against year for each site, after taking logs (adding 1 to each count to allow for zeros). The regression slopes for time periods 2009-2014 and 2010-2015 were analysed for summer and winter site counts, respectively. 'Large' increases or decreases refer to slopes equivalent to more than approximately 20% per year, and the 'no change' category refers to changes of less than approximately 2% in either direction (figures are approximate due to the distorting effect of the constant in the log transformation).

3. Results

3.1. Monitoring Dataset

Following requests for data that were circulated to the regions, the following survey records were sent to BCIreland and added to the main database (Table 2).

Table 2: The number of records imported to the Access database per survey season.

Year	Winter	Summer
2007	48	3
2008	55	20
2012	13	151
2013	99	147
2014	113	157
2015	126	n/a
Total	*454*	*478*

These records include null counts where no access was possible (e.g. due to flooding), multiple counts in the same season at some sites, and some records for species other than the lesser horseshoe bat. Some additional records outside the main survey dates were also imported to the Access database.

Following a review of the database in April 2014, 18 duplicated records were found and subsequently deleted.

The number of records on the database currently stands at 4,132 but this includes some records for other species and data that cannot be used in trend analysis due, for example, to insufficient information in the CorrectDate field.

Data received from the NPWS and VWT is of a very high standard. Survey data received for winter 2015 on newly modified Excel spreadsheets had very few issues that needed to be queried, thus ensuring efficient processing and importing.

For summer 2014, 157 discrete survey records were provided. When null counts, counts of other species, counts carried out outside the survey period (+1week) are removed, 128 records remained. These related to counts at 102 sites. Dual or multiple counts were carried out at 23 sites, where more than one count was carried out within the survey period the maximum count was retained. In total, a maximum of 8,727 bats were counted during the summer monitoring period in 2014 at these 102 sites. No bats were recorded at 14 sites, six of which are located in Co. Limerick. The maximum count at any one site was of 420 bats at William King, Kilgarvan, a VWT site, (Site Code 522) on June 24th 2014. In summer 2014 the mean summer roost size was 86 and the median was 44. This compares with a mean summer roost size in 2013 of 79 and median roost size of 49.

In winter 2015 counts were carried out at 105 sites with additional repeat counts or counts of other species conducted at 12 sites. The sum of maximum counts for all 105 sites in winter 2015 was 6,508. Counts at 93 sites contributed to the winter trend analysis. Sites are only included in the monitoring scheme when lesser horseshoe bats have been recorded at the site at least once and where counts have been carried out at a site in at least two years during the time series.

The maximum number of bats in a hibernation site was recorded at Newgrove House, Co. Clare (Site Code 056) where 962 bats were counted on January 21st 2015. Zero bats were recorded at 13 sites, five of which are located in Co. Limerick. The mean number of bats per winter roost in 2015 was 62 and the median was 13. This compares with a mean and median in 2014 of 56 and 11, respectively.

In summer 2014 all counts were carried out by 28 individuals including staff of NPWS and VWT, their assistants and two ecological consultants. Counts in winter 2015 were carried out by 30 individuals, mainly NPWS staff.

3.2. Winter Trends

The median date of observation does vary between years and average counts vary with the observation date, so this is allowed-for in the analysis.

Data from surveys conducted between 26th December and 7th March were used. Roche *et al.* (2012) highlighted the effect of day number during the survey period on mean winter counts with numbers falling off towards spring. In order to account for this, a linear trend with day number in the survey period is used below.

For the 2012 report (Roche *et al.*), 2009 was used as the base year and this has been retained in the current analysis, as it has one of the biggest sample sizes. The fitted curve has six degrees of freedom; this is rather less than the default suggested by the Fewster *et al.* (2000), but seems sensible given that, while there is a long run of data, the sample size is small for many of the earlier years.

Results are shown below in Figure 2 and Table 3. As in the previous analysis, there is a fairly consistent increase which tailed off after 2003. However, higher counts over the last three winters strongly suggest that the population may again be increasing.

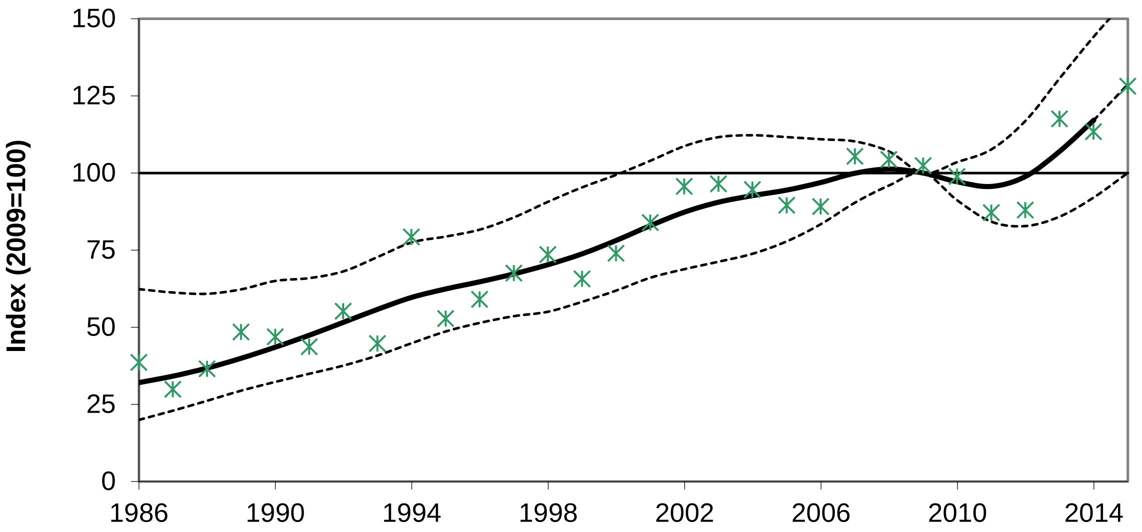

Figure 2: Results of the GAM model for lesser horseshoe bat winter counts using day number as a covariate. Stars are estimated annual means and are shown to demonstrate variability around the fitted line. The heavy black line is the fitted Generalised Additive Model (GAM) curve with 95% confidence limits shown by the lighter broken lines. The end of the smoothed trend is shown with a broken line to illustrate uncertainty for 2014-2015 and the possibility that the slope will change with coming years' data.

Table 3: GAM results with 95% confidence limits (129 hibernation sites contribute to the trend). Using day number as a covariate. 1986 refers to winter 1985-86 and similarly for other years.

		Counts			Index 2009 = 100					
					smoothed		95% conf limits		unsmoothed	
year	**counts**	**sites**	**Mean**	**s.e.**	**estimate**	**s.e.**	**lower**	**upper**	**estimate**	**s.e.**
1986	17	16	48.7	14.8	32.1	10.8	20.0	62.4	36.1	12.7
1987	16	11	54.1	10.0	34.2	9.5	23.0	61.3	27.5	8.7
1988	17	16	65.1	12.0	36.8	8.7	26.2	60.9	34.2	8.4
1989	3	3	77.7	31.2	40.0	8.2	29.5	62.3	46.1	8.8
1990	7	5	137.9	32.3	43.6	8.1	32.3	65.0	44.5	16.7
1991	7	5	126.3	14.5	47.5	7.8	35.0	66.0	41.3	9.8
1992	12	9	104.8	22.5	51.6	7.9	37.6	68.2	52.7	11.8
1993	15	13	57.8	22.1	55.8	8.4	40.9	72.8	42.3	13.7
1994	38	34	40.9	13.3	59.7	8.5	44.9	77.5	76.8	14.8
1995	16	12	48.4	16.3	62.4	7.9	48.7	79.4	50.4	9.3
1996	16	16	55.6	21.3	64.8	7.8	51.5	81.7	56.6	9.9
1997	21	20	72.1	19.1	67.3	8.5	53.6	85.7	65.2	9.5
1998	6	6	175.2	43.7	70.3	9.5	55.1	90.7	71.1	16.3
1999	13	12	80.4	22.2	73.8	10.1	58.3	95.4	63.3	14.9
2000	12	12	58.8	28.0	78.2	10.0	61.9	99.4	71.6	12.5
2001	27	26	65.1	16.5	83.0	9.9	66.1	104.0	81.5	9.6
2002	9	9	126.2	45.5	87.4	10.2	68.9	108.8	93.2	17.1
2003	10	9	84.2	38.4	90.6	10.3	71.3	111.7	94.0	24.8
2004	12	9	101.7	44.3	92.7	9.7	73.9	112.3	92.2	27.2
2005	21	12	111.0	18.3	94.5	8.5	77.9	111.7	87.1	14.1
2006	83	82	51.4	9.7	97.0	7.0	83.5	111.0	86.7	9.0
2007	46	46	76.3	14.8	100.0	5.1	90.4	110.3	103.0	7.3
2008	55	51	75.1	14.1	101.3	2.8	96.0	107.0	102.0	7.2
2009	98	90	60.8	10.2	100.0	0.0	100.0	100.0	100.0	0.0
2010	91	84	69.9	12.0	97.2	3.2	91.1	103.6	96.4	10.9
2011	99	89	56.7	9.4	95.7	6.1	84.2	107.7	84.8	13.9
2012	85	77	50.6	9.6	98.9	8.7	82.8	117.0	85.5	13.1
2013	89	86	58.3	13.2	107.1	11.1	85.9	130.7	115.1	15.4
2014	98	93	56.9	11.4	117.2	12.8	92.1	144.3	111.0	15.1
2015	99	93	61.2	13.0	128.8	14.3	100.1	156.7	125.7	14.7

3.3. Summer Trends

The results presented here use the full May to August period, with a covariate to adjust for the linear effect of day number in the year. The GAM curve is fitted with 6 d.f. which is the default for this number of years. Results are similar to those from the last analysis (Roche, Langton & Aughney 2012). There is some sign that the curve which dipped slightly downwards between 2012 and 2013, has now started increasing, but the confidence limits are comparatively wide and encompass the 100 baseline.

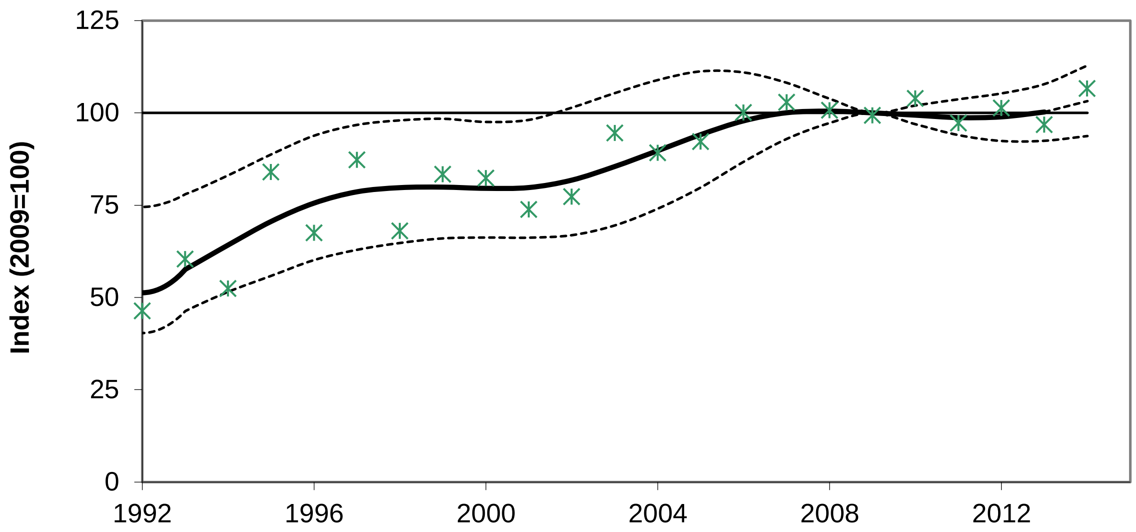

Figure 3: Results of the GAM model for lesser horseshoe bat summer counts using day number as a covariate. Stars are estimated annual means and are shown to demonstrate variability around the fitted line. The heavy black line is the fitted Generalised Additive Model (GAM) curve with 95% confidence limits shown by the lighter broken lines. The end of the smoothed trend is shown with a broken line to illustrate uncertainty for 2014-2015 and the possibility that the slope will change with coming years' data.

Table 4: GAM results with 95% confidence limits (189 sites contribute to the trend). Using data from 1st May to 31st August with day number as a covariate.

	Counts				Index 2009 = 100					
					smoothed		95% conf limits		unsmoothed	
year	counts	Sites	Mean	s.e.	estimate	s.e.	lower	upper	estimate	s.e.
1992	18	13	68.8	17.0	51.3	8.9	40.4	74.5	47.1	10.5
1993	24	11	77.1	13.9	57.6	8.3	46.3	78.0	61.1	13.7
1994	12	9	87.4	19.8	64.2	8.1	51.5	83.1	53.2	15.1
1995	18	14	91.0	23.0	70.6	8.3	55.9	88.7	84.7	15.4
1996	3	3	73.3	23.3	75.6	8.6	60.1	93.8	68.2	73.2
1997	33	25	89.0	14.6	78.6	8.7	62.9	96.7	88.0	11.8
1998	26	20	56.1	16.5	79.7	8.5	64.8	98.0	68.7	19.6
1999	80	60	56.4	7.6	79.9	8.3	66.0	98.4	84.1	12.9
2000	45	38	86.2	11.5	79.6	8.2	66.2	97.5	83.1	9.9
2001	48	28	92.5	10.4	79.8	8.4	66.2	98.1	74.5	11.4
2002	42	37	79.6	11.4	81.8	8.7	66.9	101.4	78.0	11.3
2003	34	22	73.6	13.1	85.5	9.1	69.5	105.3	95.3	16.2
2004	57	46	72.3	10.6	89.8	8.9	74.1	108.9	89.9	13.1
2005	31	24	57.1	7.2	94.1	7.9	79.8	111.2	92.9	15.1
2006	125	118	65.0	7.2	97.8	6.1	86.8	110.9	100.8	8.4
2007	106	90	93.0	9.8	100.0	4.0	92.9	108.1	103.6	8.4
2008	91	72	101.5	9.9	100.5	1.7	97.3	103.8	101.4	5.8
2009	151	120	75.7	7.6	100.0	0.0	100.0	100.0	100.0	0.0
2010	68	48	104.7	13.7	99.4	1.3	96.9	102.0	104.6	4.6
2011	131	103	82.7	7.5	98.7	2.5	94.0	103.7	97.9	5.1
2012	133	99	97.9	8.8	98.9	3.3	92.4	105.3	102.0	5.1
2013	129	107	86.1	8.4	100.2	3.8	92.4	107.8	97.5	5.4
2014	138	110	91.1	9.0	103.2	4.7	93.7	112.8	107.3	5.9

3.4. Power Analysis

Three separate tranches of power analysis were carried out on the data under 3 different scenarios.

a) all sites counted every year

b) a core of sites are counted each year, with the remaining sites counted every third year (i.e. on a rolling basis, one third of the remainder counted each year).

c) in the first three years annual counts are conducted at all sites. A core of sites are then counted each year but the remainder are counted every third year in the same season, e.g. years 6, 9, 12 etc.

3.4.1. Power Analysis of Winter Counts

Results for winter counts are shown in Table 5. These are based on the variances of counts between 26th December and 7th March. Since most roosts in this dataset are only counted once each year during this period, power estimates were produced for one count per site per year (i.e. the traditional approach of counting all sites each year) (Table 5a). These are then compared with an alternative in which a core of sites are counted each year, but the remainder are counted every third year (i.e. either by the remainder being divided into three and counted on a rolling basis (Table 5b) or all remaining sites counted in years 6, 9, 12 etc. (Table 5c)). Note that when the total number of sites is 30 or less, half the sites are considered as core sites.

Table 5: Number of years (including the extra years needed at either end of the GAM curve) to achieve 80% power for lesser horseshoe winter roost counts. While the number of years must be an integer in reality, results are shown here with one decimal place to aid comparisons. Simulations used a maximum of 28 years and '>28' indicates that 80% power was not achieved in this period.

a) All sites counted each year

	Years for 80% power					
No. of Sites	**Red alert (50% decline over 25 yrs)**		**Amber alert (25% decline over 25 yrs)**		**50% increase over 25 yrs**	
	Estimate	**s.e.**	**Estimate**	**s.e.**	**Estimate**	**s.e.**
20	19.3	1.8	>28		>28	
30	16.7	1.4	>28		26.3	1.4
40	14.1	0.8	>28		23.7	1.0
50	13.5	0.8	>28		19.8	0.6
75	11.6	0.6	22.5	1.9	18.2	0.7
100	10.7	0.5	20.8	1.5	15.5	0.7
125	9.7	0.4	20.1	1.5	14.9	0.5
150	9.5	0.4	18.2	1.2	13.2	0.5

b) Sites counted every third year on a rolling basis, except core sites counted every year. No. of Sites includes 30 core sites except where total ≤ 30 in which case half are considered core sites.

	Years for 80% power					
No of Sites	**Red alert (50% decline over 25 yrs)**		**Amber alert (25% decline over 25 yrs)**		**50% increase over 25 yrs**	
	Estimate	**s.e.**	**Estimate**	**s.e.**	**Estimate**	**s.e.**
20	21.3	1.5	>28		>28	
30	20.1	1.8	>28		>28	
40	15.7	1.0	>28		24.9	0.9
50	15.9	1.2	>28		23.8	0.8
75	13.7	0.8	>28		21.8	0.7
100	13.2	0.8	27.5	2.6	20.1	0.9
125	12.8	0.8	26.3	3.2	18.7	0.8
150	12.8	0.8	23.1	1.8	16.5	0.7

c) Sites counted in years 1, 2, 3, 6, 9, etc., except core sites counted every year. No. of Sites includes 30 core sites except where total ≤ 30 in which case half are considered core sites.

No. of Sites	Years for 80% power: Red alert (50% decline over 25 yrs)		Amber alert (25% decline over 25 yrs)		50% increase over 25 yrs	
	Estimate	s.e.	Estimate	s.e.	Estimate	s.e.
20	20.4	1.5	>28		>28	
30	19.3	1.5	>28		>28	
40	15.2	1.0	>28		24.3	0.9
50	13.2	0.6	>28		22.9	1.1
75	13.0	0.6	28.0	2.8	22.2	1.3
100	12.5	0.7	23.7	2.0	18.3	0.7
125	12.0	0.9	24.2	2.4	18.5	0.6
150	10.9	0.7	22.3	1.5	16.7	0.7

Note: 'sites' refers to the total sites, not the number counted each year. For example, for 150 sites the number counted each year is 70 (30+120/3).

Only counting every third year has a considerable impact on power, but in scenario B this may be partly attributable to the fact that there is an insufficient baseline of annual counts (i.e. counts are not carried out in all sites in years 1, 2 & 3). In scenario C, annual counts are carried out at all sites for the first three years, which mimics more closely the real situation, whereby we would continue to use 2009 or some other year with a large number of counts as a baseline.

The real difference in power between the two scenarios (B & C), whether counting the remaining sites on a rolling basis or in one tranche every three years, is therefore, likely to be negligible.

It appears that detection of amber alert levels of decline are particularly impacted for winter counts. For example, with 75 sites counted per annum an amber alert decline can be detected 22.5 years, but with scenario B a core of 30 and an additional 45 (i.e. 15 counted every third year), an amber alert decline is not detected within 28 years and with scenario C is just detected at the 28 year cut-off.

3.4.2. Power Analysis of Summer Counts

Results for summer counts are shown in Table 6. These are based on the shorter summer period (days 137 to 194) in order to avoid problems of simulating the covariate (day number). Power estimates are again shown for one count per site per year counting all sites each year (A), and two alternative scenarios (B & C) for counting the non-core sites every third year.

Table 6: Number of years (including the extra years needed at either end of the GAM curve) to achieve 80% power for lesser horseshoe summer roost counts. While the number of years must be an integer in reality results are shown here with one decimal place to aid comparisons. Simulations used a maximum of 28 years and '>28' indicates that 80% power was not achieved in this period.

a) All sites counted each year

	Years for 80% power					
	Red alert (50% decline over 25 yrs)		**Amber alert (25% decline over 25 yrs)**		**50% increase over 25 yrs**	
Sites	**Estimate**	**s.e.**	**Estimate**	**s.e.**	**Estimate**	**s.e.**
20	13.4	0.5	>28		25.4	1.7
30	11.4	0.5	23.8	1.2	19.1	0.9
40	10.5	0.4	21.0	0.9	16.7	0.8
50	9.7	0.4	18.3	1.1	15.3	0.8
75	8.6	0.3	14.8	0.8	12.4	0.5
100	8.1	0.3	13.1	0.6	11.1	0.4
125	7.9	0.2	12.7	0.7	10.4	0.5
150	7.0	0.3	11.6	0.5	10.3	0.5

b) Sites counted every third year, except core sites counted every year. No. of Sites includes 30 core sites except where total ≤ 30 in which case half are considered core sites.

No. of Sites	Years for 80% power Red alert (50% decline over 25 yrs)		Amber alert (25% decline over 25 yrs)		50% increase over 25 yrs	
	Estimate	s.e.	Estimate	s.e.	Estimate	s.e.
20	16.9	0.9	>28		>28	
30	12.9	0.6	27.3	1.5	22.2	1.1
40	11.2	0.4	22.9	1.8	18.8	1.4
50	11.1	0.4	21.5	1.2	18.2	1.0
75	10.5	0.4	20.1	1.0	15.6	0.8
100	10.1	0.4	18.1	0.9	14.5	0.7
125	9.6	0.5	17.0	1.2	14.0	0.7
150	8.8	0.3	15.1	0.7	12.6	0.6

c) **Sites counted in years 1, 2, 3, 6, 9, 12 etc., except core sites counted every year.** No. of Sites includes 30 core sites except where total ≤ 30 in which case half are considered core sites.

No. of Sites	Years for 80% power Red alert (50% decline over 25 yrs)		Amber alert (25% decline over 25 yrs)		50% increase over 25 yrs	
	Estimate	s.e.	Estimate	s.e.	Estimate	s.e.
20	14.6	0.6	>28		>28	
30	13.0	0.5	26.0	1.5	20.7	1.1
40	10.9	0.3	22.1	1.0	16.5	0.6
50	10.3	0.5	20.9	1.0	16.1	0.7
75	9.9	0.4	18.3	1.0	14.5	0.9
100	8.7	0.2	16.7	0.7	13.2	0.6
125	8.4	0.2	16.1	0.6	12.8	0.6
150	8.2	0.1	15.2	0.9	12.3	0.8

Note: 'sites' refers to the total sites, not the number counted each year. For example, for 150 sites the number counted each year is 70 (30+120/3).

From these results the summer data can be seen as having greater power to detect trends as was reported in Roche *et al.* (2012). The decrease in power under the two alternative scenarios is fairly similar to the decrease in power for winter counts, but the winter counts have lower power to detect trends in the first instance. Therefore, while the reduction in power is considerable, particularly for amber alert declines, the power of the data remains quite robust under the alternative, reduced sampling scenarios.

3.5. Climate Data

To explore the relationship between April/May temperatures and population size described for the greater horseshoe bat by Ransome and McOwat (1994), unsmoothed summer counts were regressed against April/May temperatures from the same year. The relationship was found to be of borderline significance (t=2.15 with 19 d.f., P=0.045) and is illustrated in Figure 4a.

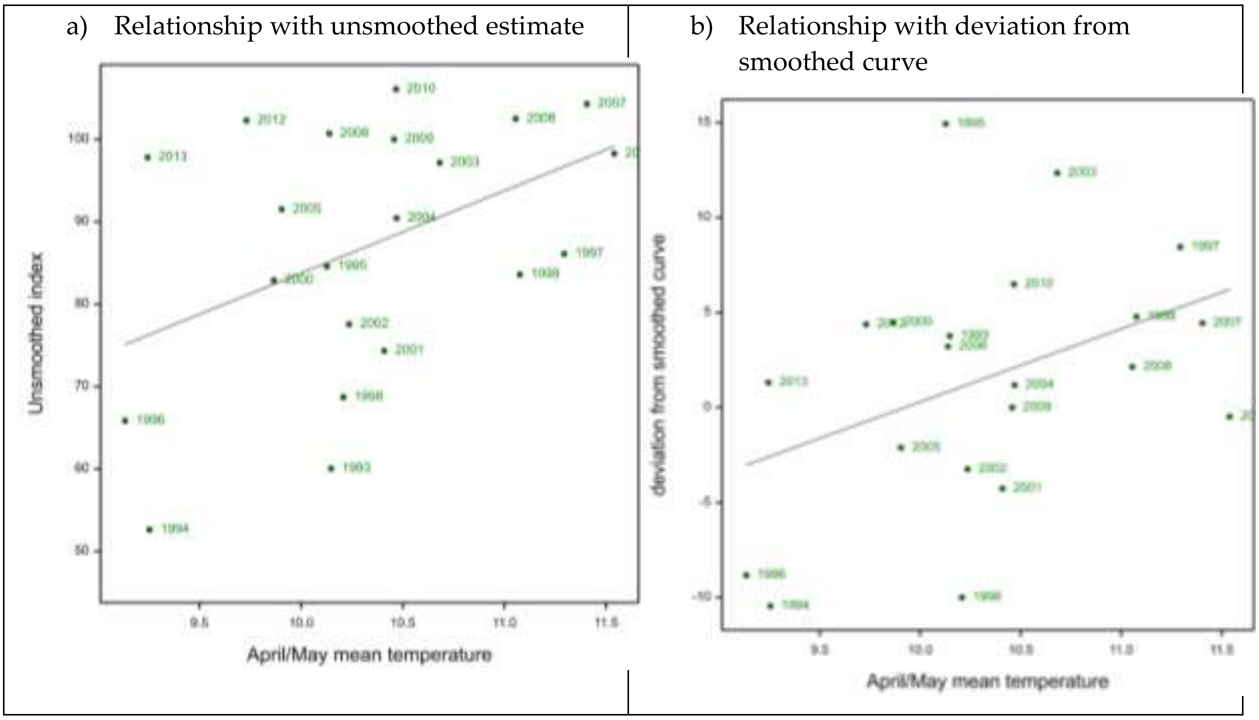

Figure 4 a, b: Relationship between yearly summer lesser horseshoe bat estimates and Met Éireann derived temperature data for April and May. A. shows the unsmoothed estimated and B. shows the relationship between temperature and the deviation of yearly estimates from the smoothed trend curve.

It is also relevant to consider whether the deviations of the unsmoothed indices from the smoothed curves are related to the April/May temperatures; this would detect any tendency for years that were warm in this period to give higher summer counts than would be expected from the long-term trend. Again results are almost significant (t=1.90 with 19 d.f., P=0.072, Figure 4b).

Unsmoothed indices from the hibernation survey in the following winter were regressed against April/May temperatures. Results were nowhere near signficant (t=0.66 with 19 d.f., P=0.520 and t=0.22 with 19 d.f., P=0.830 for the deviations from the smoothed curve).

This could, therefore, indicate that there is no strong relationship between spring temperature and population size. Instead the significant relationship between spring temperature and summer counts might be due to increased probability of including juveniles in the summer counts when breeding was early due to warm April/May temperatures.

We also examined temperatures in the August to October period, since high temperatures at this time may facilitate fat production and improve winter survival. However, this factor does not seem to be related to populations the following winter (t=0.08 with 19 d.f., P=0.937 and t=1.55 with 19 d.f., P=0.138 for deviations from the smoothed curve). Neither is there any relationship with summer populations the following year (t=0.74 with 19 d.f., P=0.468 and t=0.09 with 19 d.f., P=0.927 for deviations).

3.6. Site Assessments

Assessment data was taken from the Site_Assessments table in the database, which contained 204 assessments from 192 sites. Two variables were created from these, one for summer counts and one for winter counts. Where assessments were done in each season (taking Oct-March as winter and May-July as summer), the appropriate assessment was used, but otherwise the assessment was assumed to be applicable to all seasons. There were only two sites where the summer and winter assessment variables differed.

3.6.1. Summer Site Assessments

Figure 5 shows the spatial distribution of the summer assessments (including those actually based on winter assessments where no summer assessment was carried out) for roosts where summer counts were made.

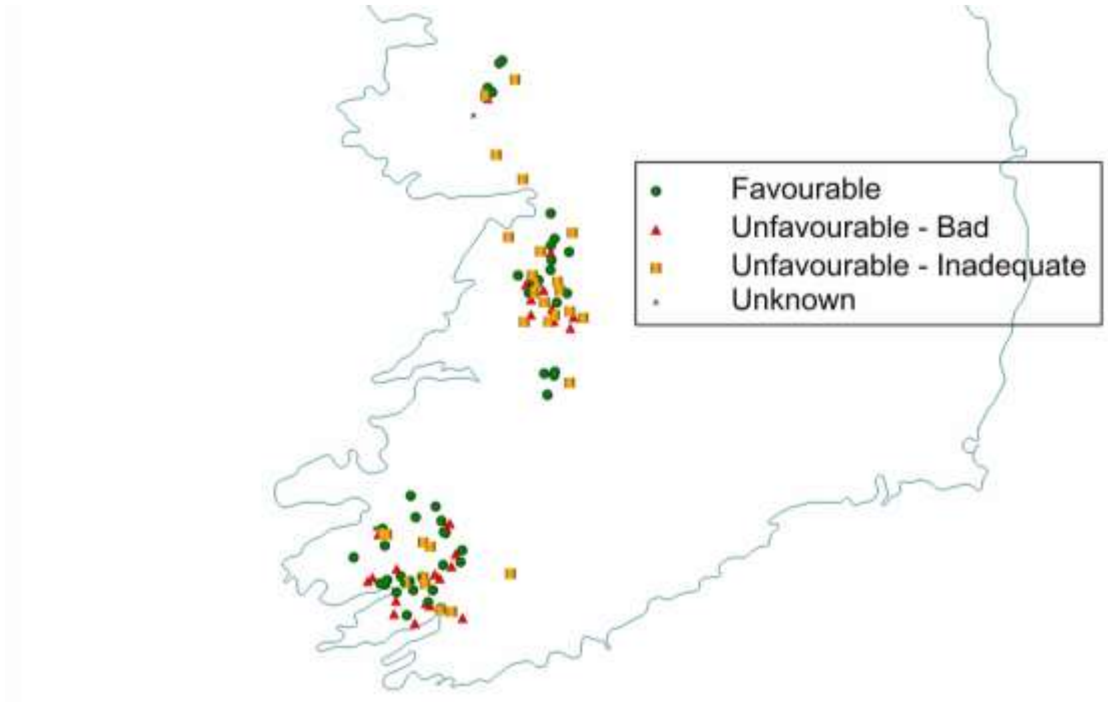

Figure 5: Summer assessment status

Differences between 2014 counts and either 2013 or 2009 ones were examined. Differences were expressed as a percentage to allow for the very different numbers counted at different sites. Where the initial count was zero, but bats were present in 2014, giving an infinite increase, the increase was taken as 100% (with the few increases over 100% also treated as 100% increase).

Results are shown in Table 7 and summarized in Figure 6. For differences since 2013, the 'bad' category shows a mean decline of 4% compared to an increase of just under 7% for 'favourable'. However, the standard errors are fairly large and a Kruskal-Wallis non-parametric test suggests that differences between groups are not significant (chi-squared=1.78 with 2 d.f., P=0.410). Changes over five years are much more convincing (Table 7b and Figure 6), with a mean decline of just under 50% for the 'bad' assessments. These differences are statistically significant (Kruskal-Wallis test, chi-squared = 16.42 with 2 d.f., P<0.001).

Table 7: Average percentage changes in summer counts

a) 2013 to 2014

	N sites	Mean	s.e.	Lower quartile	Median	Upper quartile
Summer assessment						
Favourable	48	6.7	5.1	-10.5	0.0	17.9
Unfavourable - Inadequate	25	4.2	11.1	-20.6	4.5	24.7
Unfavourable - Bad	19	-4.0	10.8	-28.3	0.0	0.0

b) 2009 to 2014

	N sites	Mean	s.e.	Lower quartile	Median	Upper quartile
Summer assessment						
Favourable	43	19.7	7.7	-15.9	15.5	47.5
Unfavourable - Inadequate	23	3.5	14.1	-46.7	-17.2	73.5
Unfavourable - Bad	17	-48.2	15.7	-100.0	-60.5	-22.3

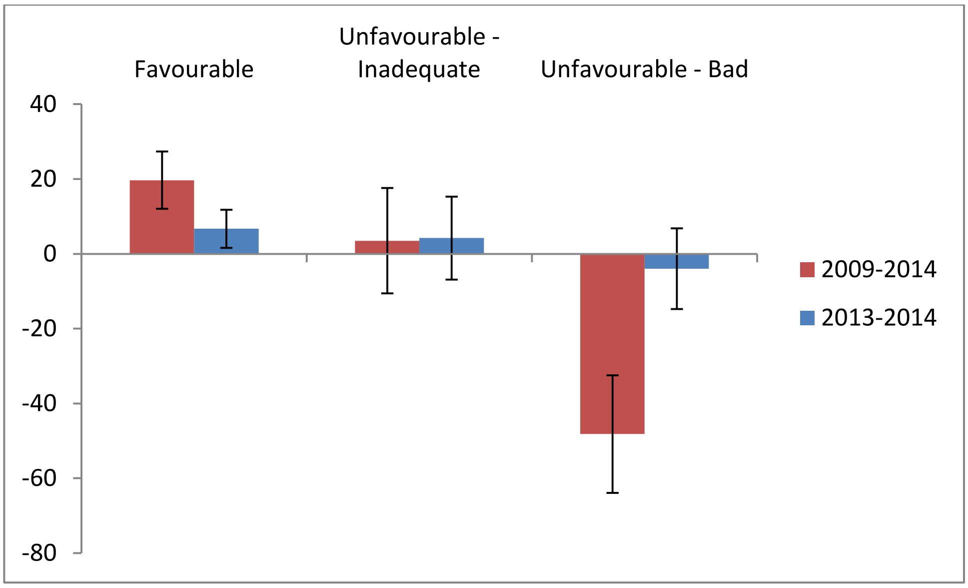

Figure 6: Chart showing mean percentage change and s.e. in roost size per status category in summer sites. Two time periods are indicated, 2009 to 2014 and 2013 to 2014. Number of sites per category can be found in Table 7 (a) and (b) above.

Table 8 shows average regression slopes for each category, ignoring sites with counts in less than four of the years 2009-14. On average, slopes are more negative for the bad category, with differences being significant using a Kruskal-Wallis test (chi-squared = 18.24 with 2 d.f., P<0.001).

Table 8: Average regression slopes against time for summer roosts

	N sites	**Mean**	**s.e.**	**Lower quartile**	**Median**	**Upper quartile**
Summer assessment						
Favourable	48	0.000	0.012	-0.012	0.008	0.034
Unfavourable - Inadequate	24	0.003	0.028	-0.063	-0.014	0.036
Unfavourable - Bad	20	-0.150	0.040	-0.342	-0.078	-0.033

Figure 7 plots out the slopes on a map. 'Large' increases or decreases refer to slopes equivalent to more than approximately 20% per year, and the 'no change' category refers to changes of less than approximately 2% in either direction (figures are approximate due to the distorting effect of the constant in the log transformation). There is no sign of any spatial pattern to the changes; indeed the lack of clustering is quite surprising, with increasing and decreasing sites frequently close together, geographically, as might be expected if bats were moving between nearby sites. Forty four of the 92 sites analysed had undergone a decline or large decline from 2009-2014.

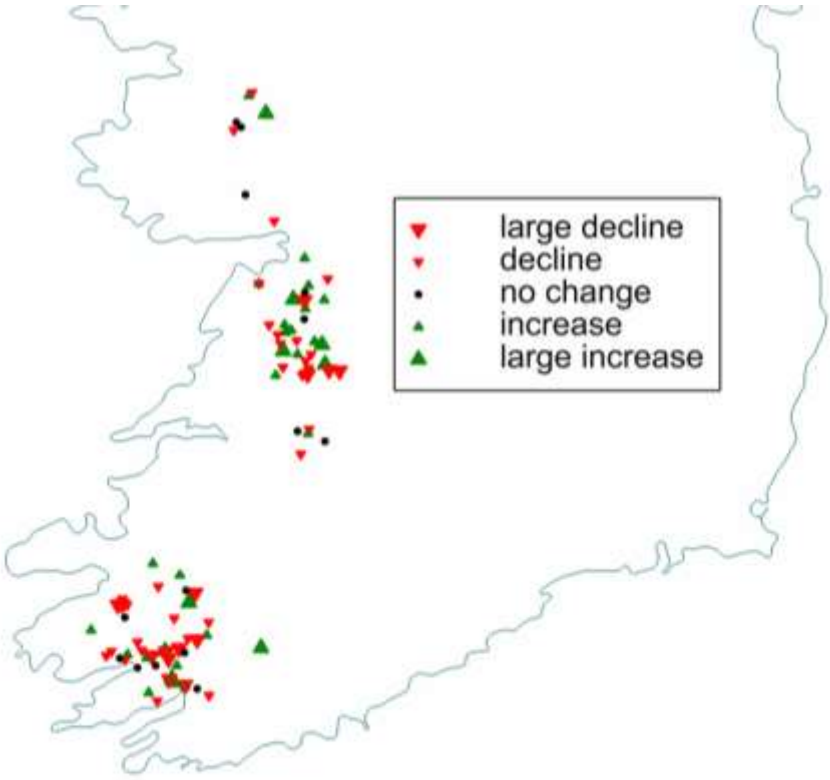

Figure 7: Map showing changes from 2009 to 2014 estimated by regression slopes for summer roosts

To further investigate this spatial pattern, some simple geo-statistical methods were applied. Figure 8 plots a variogram of the data, which shows the variance of the difference between points various differences apart, in this case grouped into 5km bands. It is also of interest that declines have been registered at some sites with 'favourable' site assessments (e.g. in Kerry - Site Code 502, Cappyantanvally Glencar; Site Code 385, Churchtown Killarney; Site Code 435, Caher Bridge, Kenmare).

The usual pattern expected in these plots is to see the variance increasing with difference, due to points close together in space being positively correlated. This one shows the reverse, with the highest value at the closest distance, suggesting that points close together might be negatively correlated. A randomisation test suggests that this pattern may be statistically significant (P=0.022), although this result should be treated with caution since it is dependent on the precise way in which the test is conducted, and the p-value is over the 5% value if different groupings of the distances are used, for example. Nevertheless, the result is certainly consistent with the theory that bats are moving between nearby roosts.

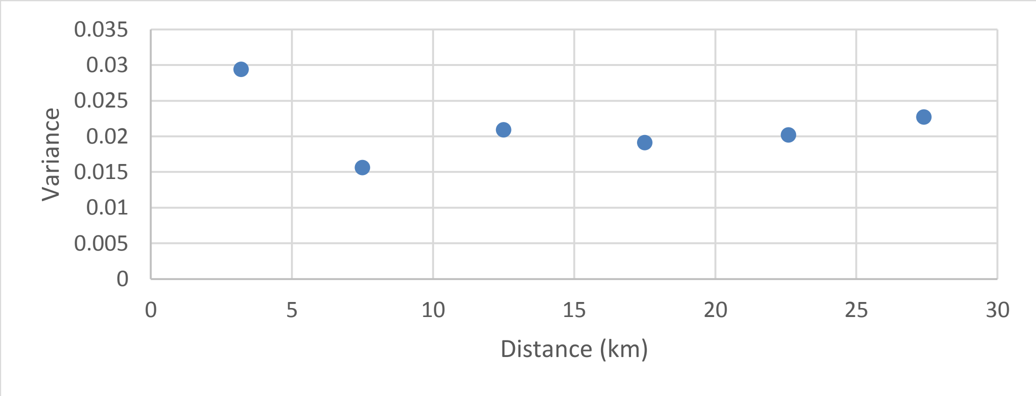

Figure 8: Variogram of the regression slopes for summer roosts

3.6.2. *Winter Site Assessments*

Figure 9 shows the assessment status for those sites with hibernation counts. There are very few hibernation sites in bad condition, and relatively few in the 'inadequate' category, so in the remaining tables these two categories are amalgamated.

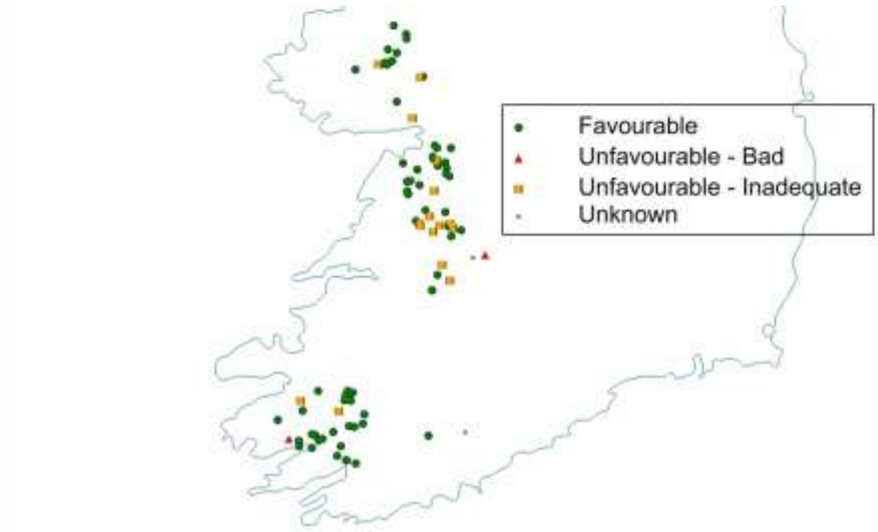

Figure 9: Map showing winter assessment status for hibernation sites (site assessments 2015)

Results for differences between years are shown in Table 9 and summarized in Figure 10. As for the summer counts, where the initial count was zero, but bats were present in 2015, giving an infinite increase, the increase was taken as 100% (with any increases over 100% also treated as 100% increase). Numbers were increasing on average from 2014 to 2015, so the mean differences are now both positive, and higher for the unfavourable sites, although this difference is not significant (Kruskal-Wallis test, chi-squared = 0.04 with 1 d.f., P=0.844). The unfavourable sites also show a more positive difference for the 2010 to 2015 comparison (Table 9b and Figure 10), but the difference is nowhere near significant (Kruskal-Wallis test chi-squared = 0.09 with 1 d.f., P=0.763). The mean regression slope (Table 10) is negative for the unfavourable group but, once again, differences in slope between the two groups are not significant (Kruskal-Wallis test chi-squared = 0.93 with 1 d.f., P=0.335).

Table 9: Average percentage changes in winter counts

a) 2014 to 2015

	N sites	Mean	s.e.	Lower quartile	Median	Upper quartile
Winter assessment						
Favourable	61	16.4	7.2	-15.8	15.4	60.4
Unfavourable	15	17.3	17.7	-30.0	20.2	85.5

b) 2010 to 2015

	N sites	Mean	s.e.	Lower quartile	Median	Upper quartile
Winter assessment						
Favourable	50	18.1	9.3	-46.3	0.0	100.0
Unfavourable	15	22.1	17.7	-8.5	0.0	100.0

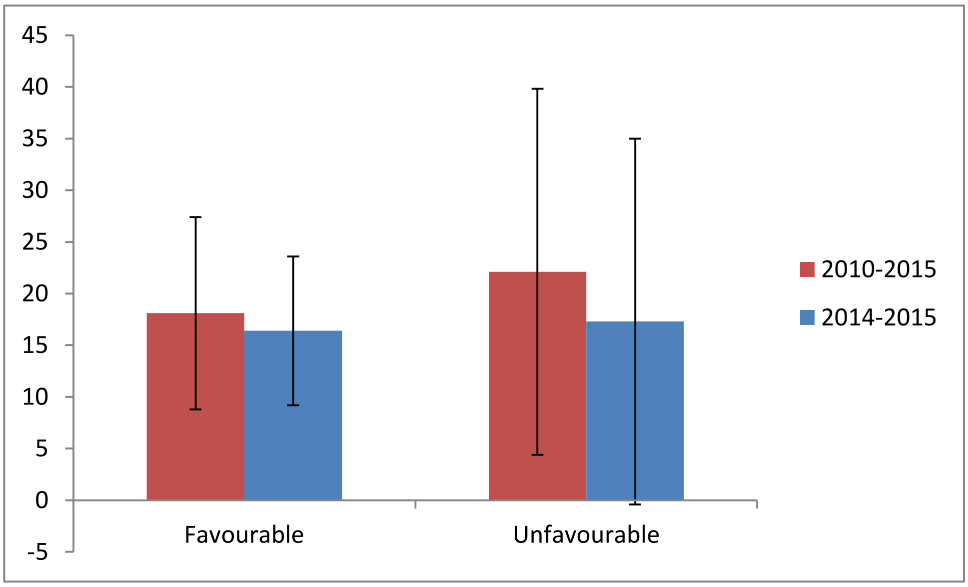

Figure 10: Chart showing mean percentage change (and s.e. bars) in roost size per status category in summer sites. Two time periods are indicated – 2010 to 2015 and 2014 to 2015. Number of sites per category can be found in Table 9 (a) and (b) above.

Table 10: Average regression slopes against time

	N sites	Mean	s.e.	Lower quartile	Median	Upper quartile
Winter assessment						
Favourable	64	0.023	0.015	-0.044	0.009	0.060
Unfavourable	14	-0.021	0.025	-0.071	-0.020	0.048

Figure 11 plots out the slopes on a map; visually there is perhaps some sign of clustering of the colours, but there is still a mix of red and green points in most areas. Figure 12 shows the variogram, this time extended to 60km on the basis that greater distances might be travelled to hibernation sites. Variances between points close together tend to be smaller, indicating some spatial correlation. Interestingly, if a finer scale is used there is some sign of negative correlations for distances less than 2km, which might suggest some movement between nearby hibernacula, but not too much should be read into this, given the instability of estimates. While just 14 of 78 sites were assessed as 'unfavourable', slopes analysis for the 2010-2015 period showed that 34 sites had in fact undergone declines or large declines in this timeframe.

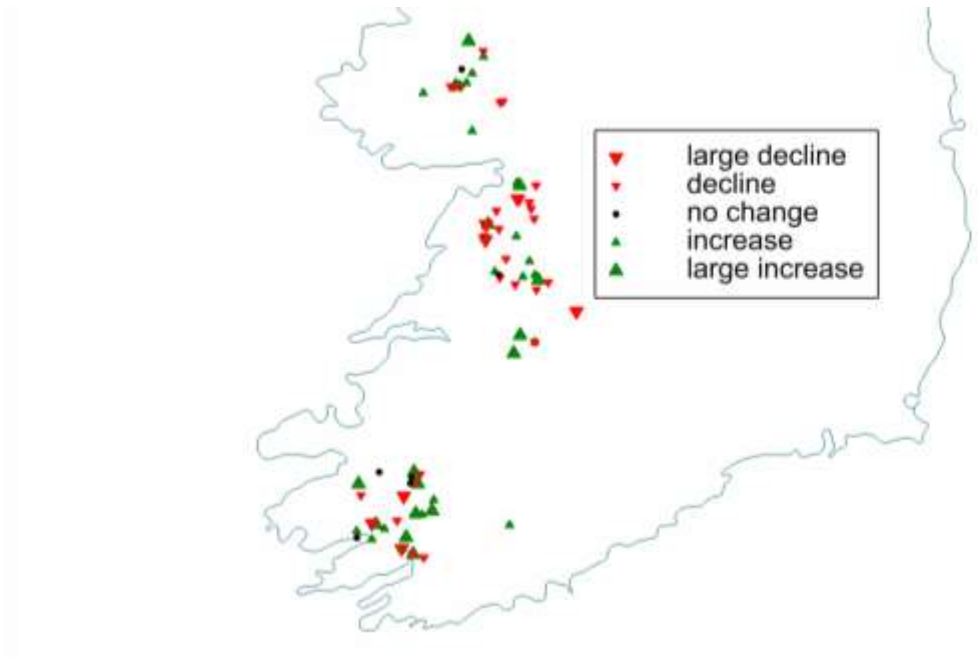

Figure 11: Map showing changes from 2010 to 2015 estimated by regression slopes for hibernation sites

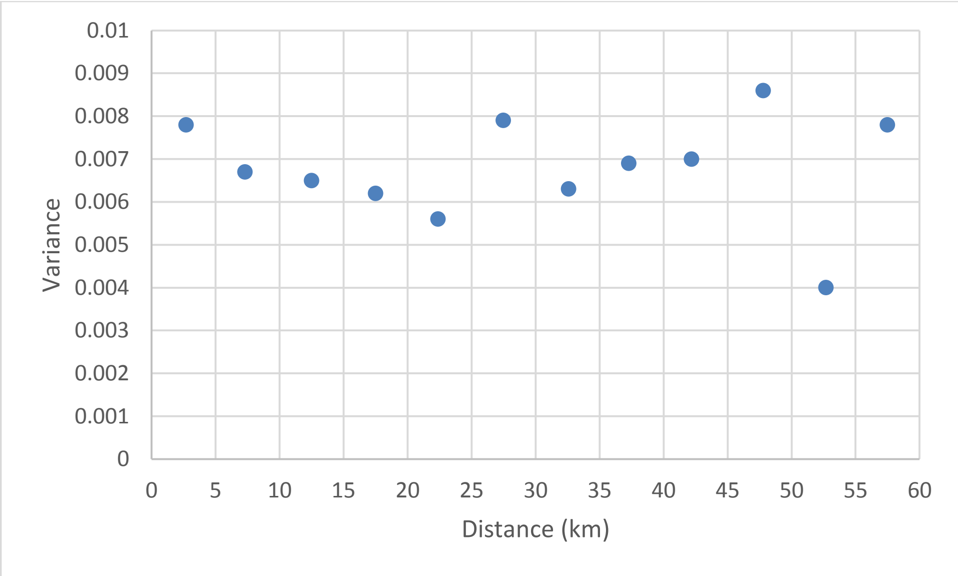

Figure 12: Variogram of the regression slopes for hibernation sites

3.6.3. Summer and Winter Site Assessments by Region

3.6.3.1. North Galway and Mayo

At the northernmost end of the species' range in Ireland, the relatively few roosts are concentrated in the Cong/Clonbur area and east of Lough Mask and most of the summer sites are stable or increasing, Figure 13. Nonetheless, there is a considerable geographical distance between the Lough Mask sites and those sites situated further south in the environs of Galway city. A key summer site ensuring connectivity is situated to the west of Lough Corrib at Ross House (Site Code 212). Although numbers have been stable at the site for the past five years this site is assessed as Unfavourable – Inadequate due to ingress of rainwater into the roof space. This site should be prioritised for remedial on-site works in partnership with the site owners.

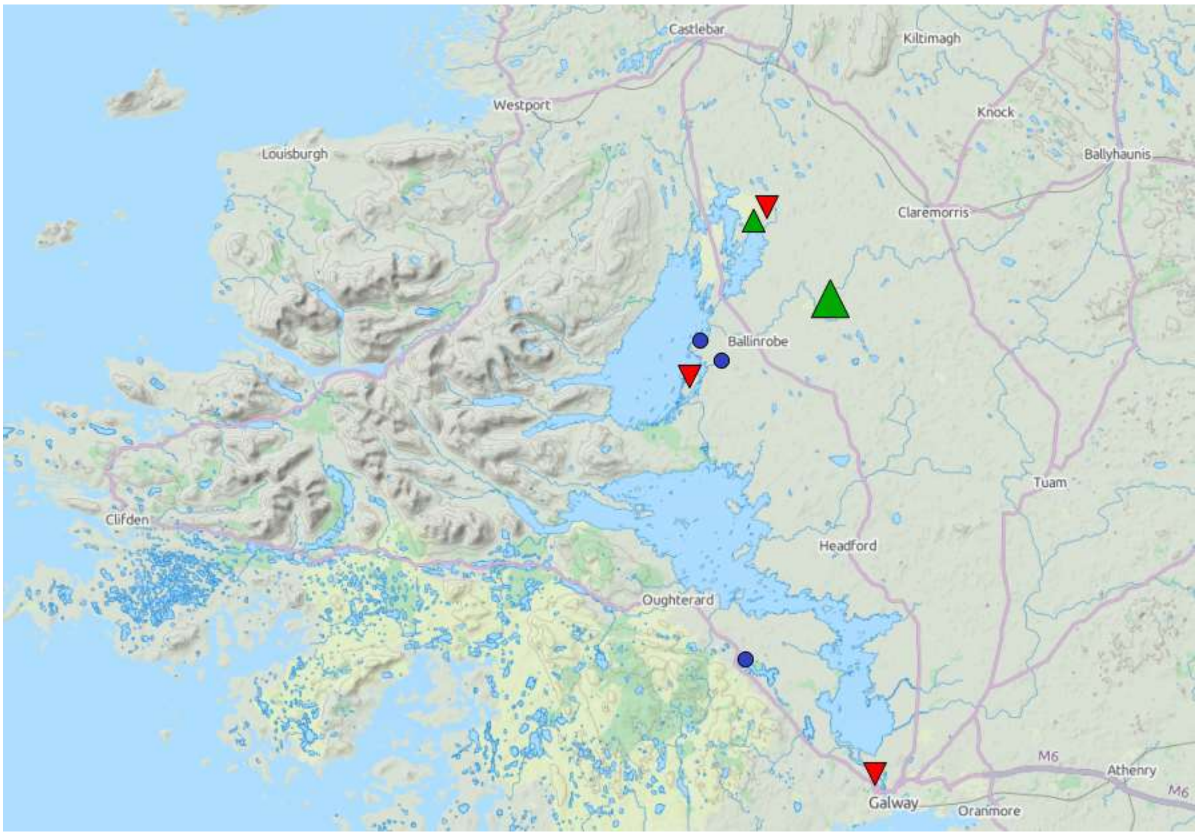

Figure 13. North Galway/Mayo, summer 2009-2014 ▲Large Increase ▲ Increase ● No Change ▼ Decline ▼ Large Decline

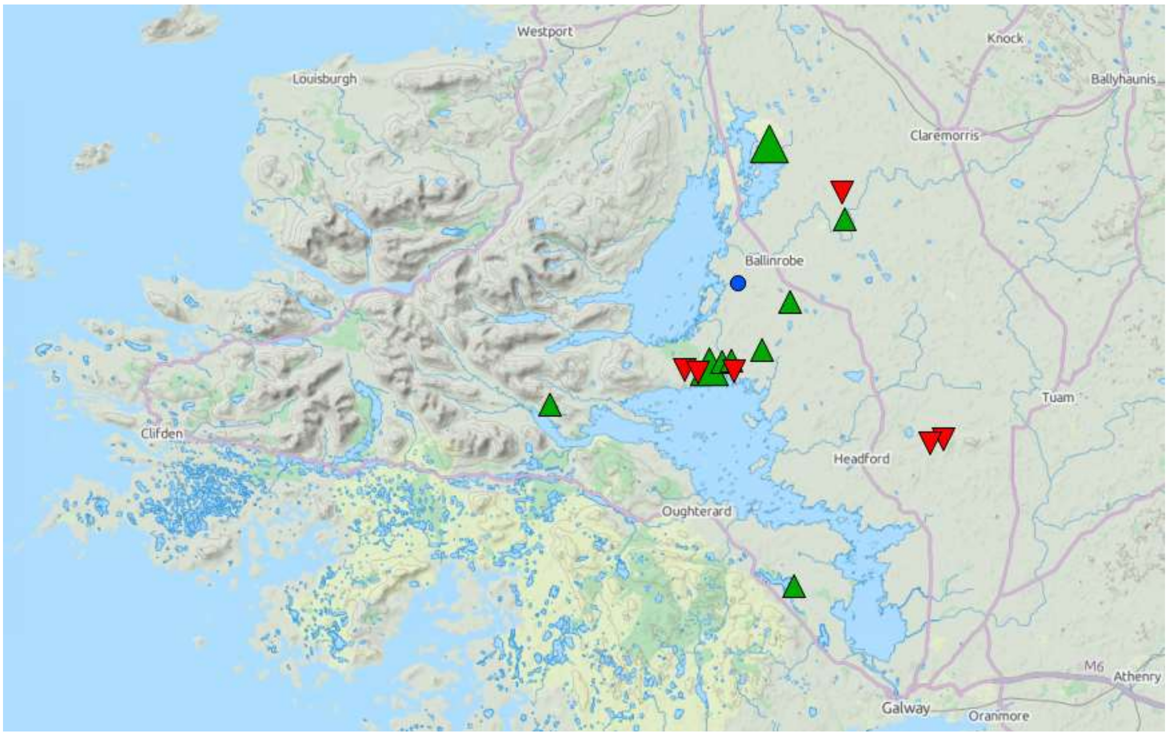

Figure 14: North Galway/Mayo, winter 2010-2015 ▲ Large Increase ▲ Increase ● No Change ▼ Decline ▼ Large Decline

Further south around Galway city a number of newly discovered winter sites for the species have not yet been added to the database for the species. These natural cave or sinkhole sites have small numbers in winter (typically less than 10 individuals) although the only known summer site at Menlo Castle is considered vulnerable. Figure 14 shows the slopes results for winter sites.

3.6.3.2. South Galway and Clare

At 10 north Clare/south Galway winter sites decreases or large decreases have occurred in the past five years, Figure 16. Increases have occurred in three sites, but of these (Site Code 244 Cloughballymore House, Site Code 263 Ballinderreen and Site Code 126 Glencurran Cave) the maximum number of bats counted was 40 individuals in Glencurran this winter, maximum numbers at the other two have not exceeded 11. At Newgrove (Site Code 56), however, numbers continue to increase year on year with just shy of one thousand individuals counted in winter 2015. Although the increase at Newgrove has not been ‘large’ over the past five years, numbers have increased by roughly 300% since 2000. It may be that more bats from north Clare and south Galway are opting to hibernate in this artificial underground site rather than natural caves in the Burren and elsewhere in the karst landscape. Possible reasons may include reduced risk of predation, less dramatic temperature fluctuations and reduced risk of natural disasters, flooding in particular. Rigorous conservation measures are needed for this site to ensure it is protected into the future.

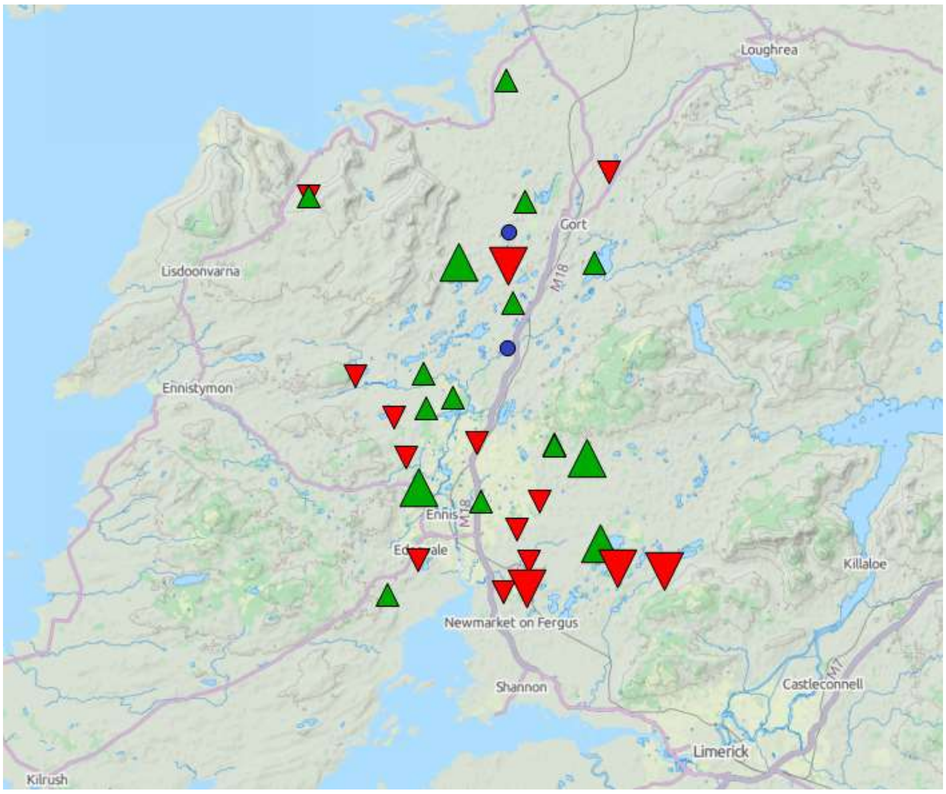

Figure 15: South Galway/Clare summer 2009-2014 ▲ Large Increase ▲ Increase ● No Change ▼ Decline ▼ Large Decline

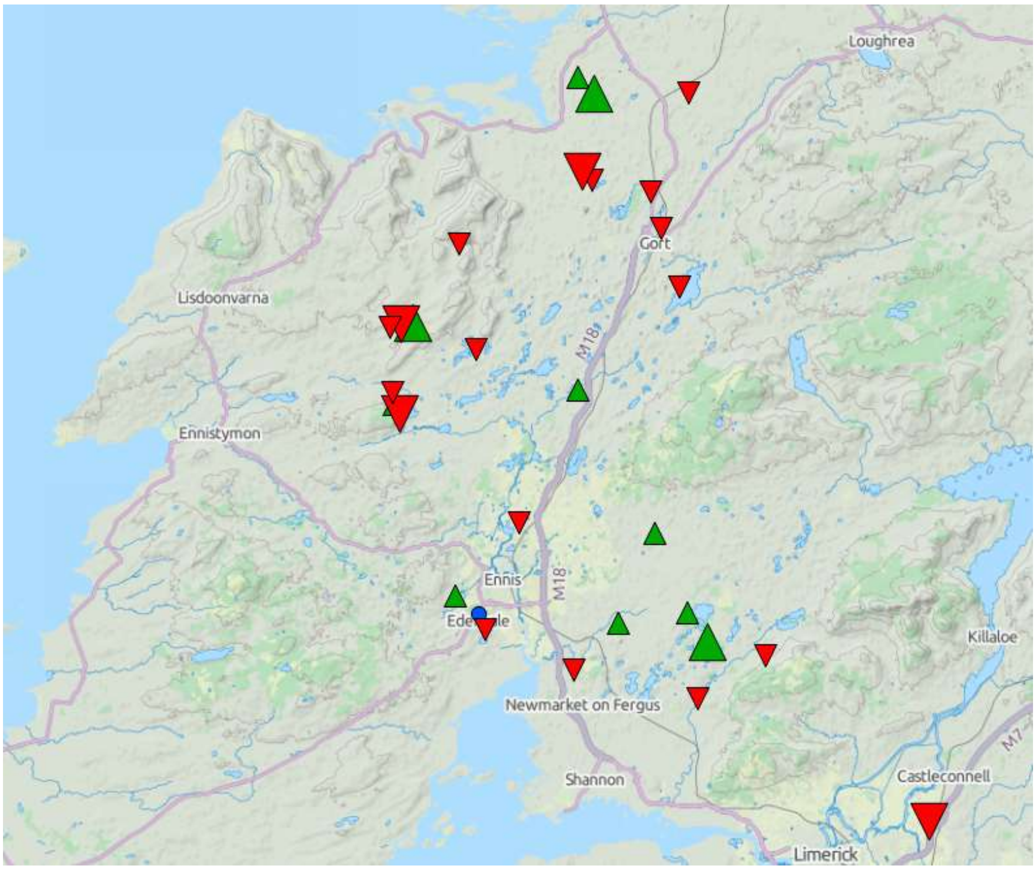

Figure 16: South Galway/Clare winter 2010-2015. ▲ Large Increase ▲ Increase ● No Change ▼ Decline ▼ Large Decline

Ongoing declines at both winter (e.g. Site Codes 51 Ratty River Cave, 59 Danes Hole, 33 Dromoland) and summer sites in south east Clare (e.g. Site Codes 27 Kilkeshin, 790 Ahaclare, 33, 730 Ballykilty Manor) is of some concern since losses there may further reduce connectivity to the already depleted Limerick population situated further south. Possible strategies to counter this are discussed.

3.6.3.3. Limerick

The situation in Limerick (Figures 17 and 18) has been the subject of some research and discussion, particularly ongoing work by the VWT. While a couple of sites there continue to hold their own the largest numbers are found at Curraghchase. Even here, however, it should be noted that numbers have not exceeded 100 since 2007. Overall, the lesser horseshoe population in Limerick is very small and the considerable distance to Kerry sites to the south and even south Clare sites to the north means that there is an ongoing risk of inbreeding or even extinction.

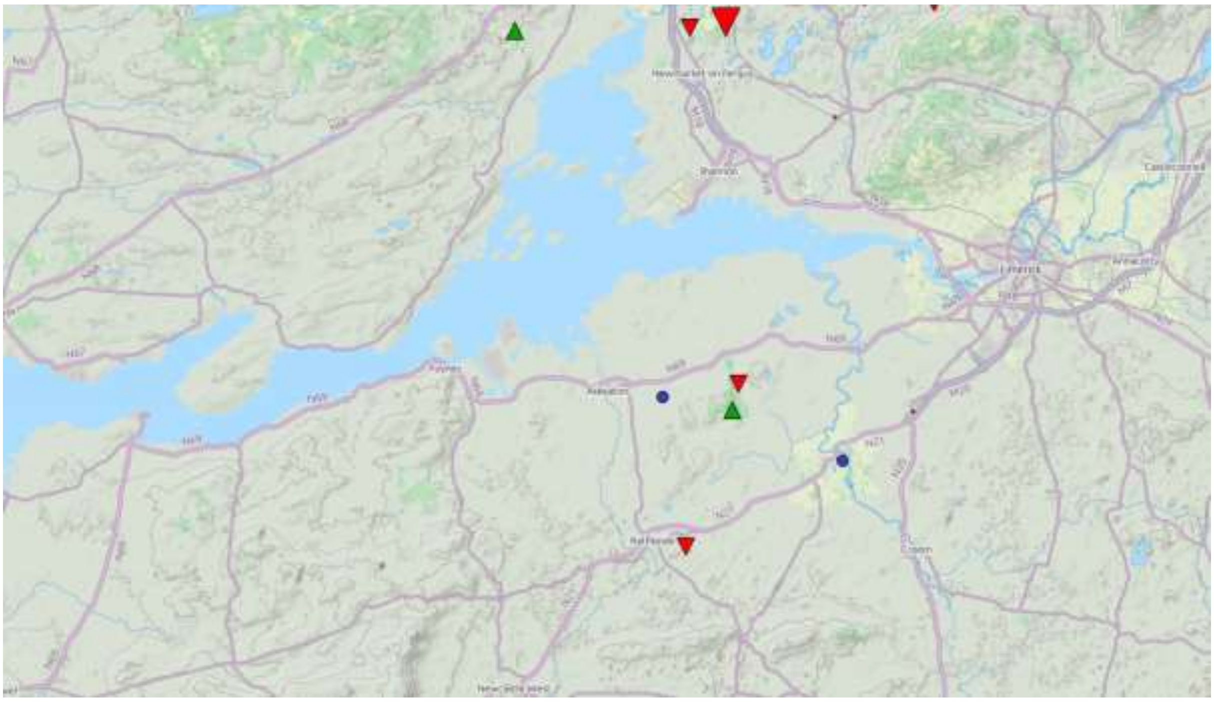

Figure 17: Limerick summer 2009-2014 ▲ Large Increase ▲ Increase ● No Change ▼ Decline ▼ Large Decline

Figure 18: Limerick winter 2010-2015 ▲ Large Increase ▲ Increase ● No Change ▼Decline

▼Large Decline

3.6.3.4. Kerry and West Cork

While on the whole there is a healthy population of the species found in Kerry and west Cork, there is some concern on the Iveragh Peninsula where moderate or large declines have occurred in 12 summer sites and increases or stable numbers have been recorded in only four sites in the past five years (Figure 19). It should also be noted that this site tally does not include those on the western shores of Lough Leane that progressed to ruinous state and have now been abandoned by bats (e.g. Site Code 295 Tomies East). The Glencar cluster of sites and locations west of Sneem appear particularly vulnerable. The situation in winter does not seem to be quite as extreme with half the 12 sites increasing compared with the other half declining or stable (Figure 20).

East of Kenmare town, declines or losses have occurred in a couple of large sites.

In the Beara peninsula the population is considered in good health and there is an available resource of derelict buildings to replace those that become ruinous and are abandoned by bats.

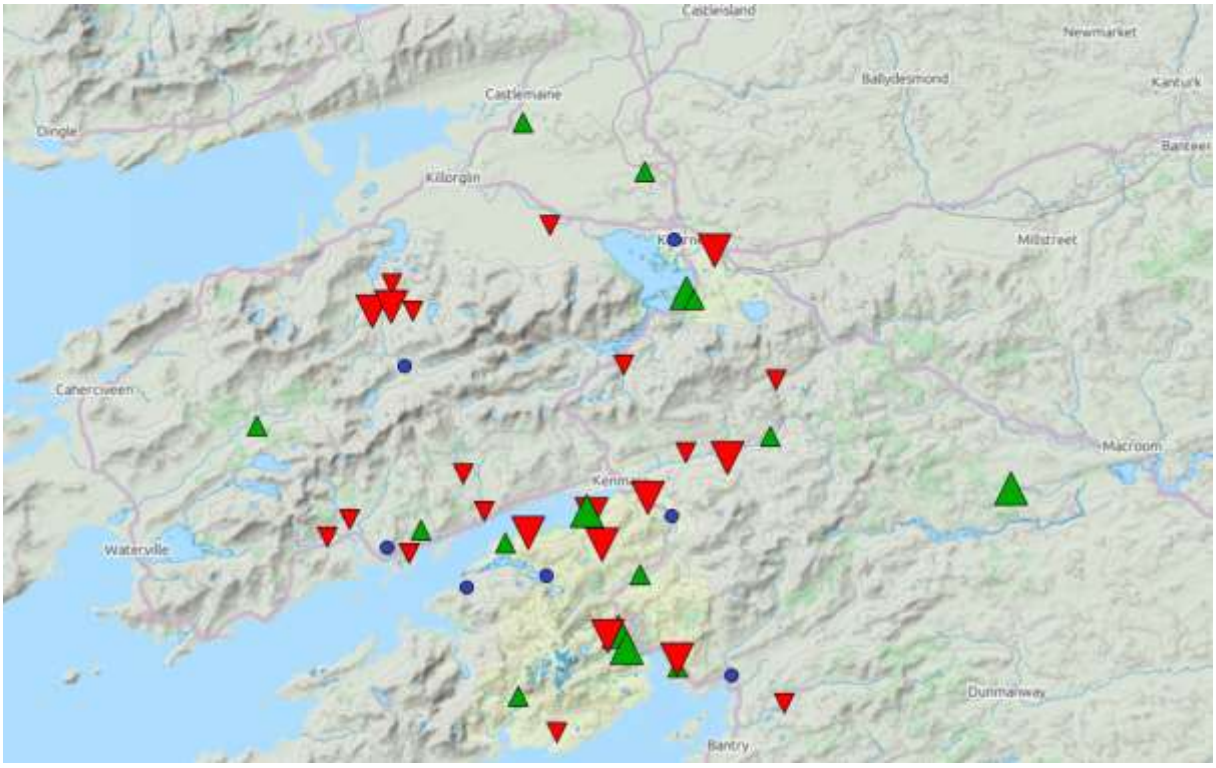

Figure 19: Kerry/west Cork summer 2009-2014 Large Increase Increase No Change Decline Large Decline

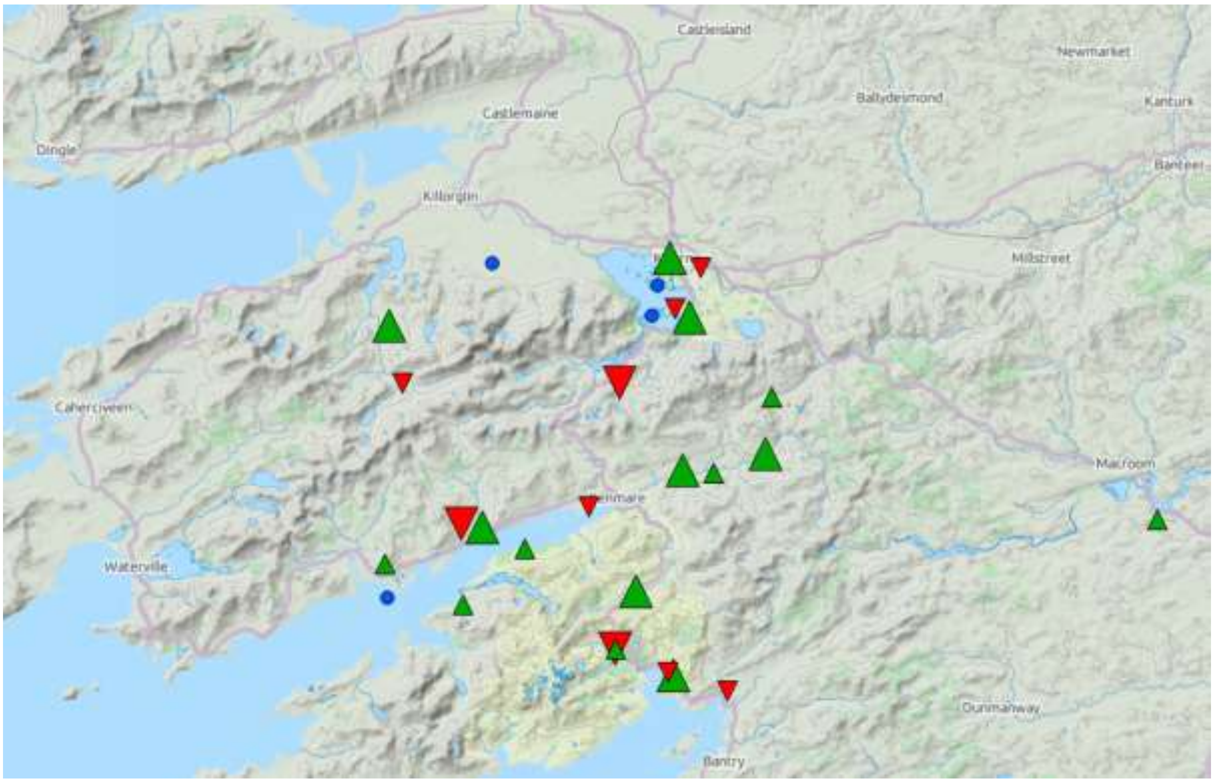

Figure 20: Kerry/west Cork winter 2010-2015 Large Increase Increase No Change Decline Large Decline

4. Discussion

4.1. Surveyors

Thirty individuals undertook the survey in winter 2015, and 28 surveyors carried out the summer counts in 2014. The surveyors comprise a very dedicated and experienced team most of whom are staff members of the NPWS and VWT. It is of some concern that the survey work is carried out by such a small team since quite a high survey load inevitably falls on relatively few individuals. There are clearly major advantages conveyed by having the survey work carried out by staff of conservation organisations, in comparison with unpaid volunteers (e.g. in-house training and equipment provision, established working relationships with roost owners etc.), but the sustainability of the scheme may be compromised in the event that a couple of key surveyors are unable to complete surveys in a particular season.

One effect of the low number of surveyors is that 10-30% of all summer surveys are carried out more than one week after the end of the designated survey period (July 7th). This may impact on trends since later counts are more likely to include newly volant juveniles. While we do take the effect of day number into account in the trend modelling process the exact impact of day number is not fully understood; keeping more rigorously to the survey dates would help circumvent this problem. Other strategies to effectively 'top up' survey capability such as recruitment of voluntary surveyors, could be considered.

4.2. Survey Coverage 2013-2015

Excellent coverage was achieved from summer 2013 to winter 2015. These survey seasons have contributed a huge body of information to the dataset. Ninety three sites contributed to data on trends in winter 2014 and 2015, while over 100 sites contributed to summer trend data in 2013 and 2014. These are widely distributed across the range for the species from Mayo to west Cork.

4.3. Dataset

In November 2013 BCIreland received the MS Access database that included 3,200 discrete records. Since then much of the data has been cleaned, verified and new data has been added. There are now 4,132 records on the database. This includes some null records and records for other bat species.

4.4. Yearly Trends

According to the trend models the lesser horseshoe bat increased significantly from the early years of the survey in the late 1980s and early 1990s. While some caution is needed when interpreting trends from early years due to low sample sizes, we can be reassured by the fact that summer and winter trends converged, at least until the late 2000s. Overall – over the past 20 years, from the GAM smoothed model, the species increased by between 60.7% (summer) and 106% (winter). The UK NBMP also reported a difference in the extent of increase recorded by winter versus summer counts. Between 1999 and 2012 the UK lesser horseshoe bat population change was 75.2% from winter counts and 65.5% from summer counts (Barlow *et al.* 2015), mirroring the trend in Ireland.

From 2012 in Ireland summer and winter trends diverged with winter counts increasing strongly but summer counts remaining stable or just recently beginning to increase (95% error bars for summer trends enclose the baseline). This mirrors the current situation in Britain where hibernation and summer trends have recently diverged for the species (S. Langton *pers. comm*.).

4.5. Power

Power analysis was repeated in spring 2014 in order to recheck the power of annual counts, but also to determine whether alternative survey strategies that optimise surveyor time would result in a significant loss of power. The scenario investigated was where a core of 30 sites would continue to be counted every year with an additional cohort of sites counted every third year. Two scenarios for how this could be done were investigated.

- One whereby the additional tranche of sites would be divided into three sets each of which would be surveyed on one of the three years, i.e. a rolling count.

- Alternatively, just core sites would be counted annually and then every three years all additional sites would be counted in the same season.

For the both scenarios a significant loss of power was evident. However, this was particularly the case for winter counts where power to detect trends is already lower than summer counts. Amber alert declines would just about be detected within 28 years with a sample of 30 core sites and 45 additional sites surveyed every three years. These results suggest that in order to ensure winter counts remain robust for detection of possible declines, annual counts should be continued at a minimum of 75-80 sites.

For trends from summer counts there is potential, provided some loss of power is considered acceptable, for optimising surveyor effort by reducing the number of sites surveyed annually. From the scenario which was investigated with 30 core sites, and an extra 70 sites surveyed every three years, robust power to detect red alerts can be achieved in less than 10 years and amber alerts within 19. In reality, in order to ensure a good selection of widely distributed sites are included in the monitoring scheme, a core of up to 50 sites would be preferable. This would also improve power.

On foot of site-assessments carried out in 2014 we now believe that reducing the number of sites counted in summer may be counter-productive since so many summer sites are prone to deterioration (see section 4.6). Monitoring deterioration of sites is very important, not only from the point of view of devising conservation strategies for the species and maintaining the roosting resource, but also in order to inform the monitoring data. If roosts in a good state are counted more frequently than sites that are less suitable this leads to a risk of bias in the trend data. We therefore need to continue to take this into account in analysing trends.

4.6. Climate

A significant positive correlation was found between spring temperatures (April and May) and lesser horseshoe bat population estimates in the corresponding summer. Ransome and McOwat (1994) discuss the relationship between spring temperature and birth timing in the greater horseshoe bat in some detail.

For the Irish lesser horseshoe bat dataset there is a possibility that the significant relationship is merely indicative that young are born earlier following warm springs and may be included in some roost counts, since no correlation was found between subsequent hibernation counts and temperatures the previous spring. No significant relationship was found between early autumn temperatures and winter estimates, or populations the following summer.

4.7. Site Assessments

Deterioration of sites is an ongoing problem for the lesser horseshoe bat in Ireland and has been highlighted by previous authors e.g. McAney *et al.* (2013). The analysis of site assessments for this report indicates that there are no specific clusters of areas where site assessments are *uniformly* bad, poor sites are distributed across the range for the species.

However, many sites with a poor assessment have had serious declines in bats in the past five years. Simple geo-spatial analysis indicates that declines in poor sites tend to be associated with increases in sites assessed as 'favourable' that are situated nearby, thus suggesting that bats can move from bad to favourable sites as conditions require.

Overall, fewer winter sites than summer sites are considered in a poor state. This reflects the reliance of the bat on disused buildings for summer that are much more prone to deterioration than the typical underground winter hibernating resource of natural caves or cellars. Nonetheless, while just 14 of 78 sites had been assessed as 'unfavourable', slopes analysis for the 2010-2015 period showed that 34 had in fact undergone declines or large declines. This may give some indication of the difficulties faced by surveyors in assessing whether a site is truly favourable for hibernating bats, but it also highlights the fact that other factors besides roost condition alone can impact on bat numbers.

While in many respects the findings are positive in that good sites are well-dispersed and the bat has widespread availability of suitable sites across its range, a number of locations may pose potential problems into the future.

A review of the range for the species on a regional basis and using the data derived from regression analysis of counts over the past five years, tentatively indicate potential for range contractions that could in the long-term pose serious risks to the species' conservation status.

Potential problem areas highlighted include:

- North Galway – between Cong and Galway city, a key known summer site here (at Ross House) is currently vulnerable to deterioration and needs remedial work in liaison with its owners to ensure continued viability. This should be a priority.

- A decline in many north Clare winter sites appears to be occurring in conjunction with increases in counts in certain sites, but particularly at Newgrove. The mechanisms at the root of this change are largely unknown but may be related to increased flooding at natural caves, temperature fluctuations or other factors. We do not suggest any strategy to counteract this phenomenon other than ensuring that very rigorous conservation measures are undertaken at Newgrove to protect this key overwintering site for Clare and south Galway.

- South east Clare sites in winter and particularly in summer have undergone declines and this may impact connectivity to the already beleaguered Limerick population. We suggest that a strategic examination of these sites is carried out and one or two are targeted for remediation and conservation.

- Limerick sites are under pressure. At the key site here, Curraghchase, numbers in either winter or summer have not exceeded 100 since 2007. Apart from the possibility of constructing purpose-built hibernacula and summer sites in suitable habitat there is currently very little potential to improve the situation for the lesser horseshoe bat in Limerick.

- In Kerry and west Cork the population is largely healthy and well dispersed. However, on the Iveragh peninsula a majority of summer sites have undergone moderate or large declines in the past five years. Key areas where declines have occurred include Glencar and Sneem. Some targeting of roosts in these areas for conservation/restoration is recommended. In addition the loss of sites west of Lough Leane within the Killarney National Park boundaries should be rectified. East of Kenmare in the Kilgarvan area there has been some decline that should continue to be monitored. It is possible that losses here will be offset by continued conservation at two VWT properties.

We propose that site assessments should be revised and re-analysed prior to the next Article 17 reporting round with due consideration given to the possibility of autocorrelation in the data if site numbers are taken into account in the process of assigning assessment categories.

Bibliography & Relevant Literature

Armitage, P. & Berry, G. (1987) *Statistical Methods in Medical Research*, 2nd ed. Blackwell Scientific Publications, Oxford, U.K.

Barlow, K.E., Briggs, P.A., Haysom, K.A., Hutson, A.M., Lechiara, N.L., Racey, P.A., Walsh, A.L. & Langton, S.D. (2015) Citizen science reveals trends in bat populations: The National Bat Monitoring Programme in Great Britain. *Biological Conservation*, **182**, 14–26.

Fewster, R.M., Buckland, S.T., Siriwardena, G.M., Baillie, S.R. & Wilson, J.D. (2000) Analysis of population trends for farmland birds using generalised additive models. *Ecology*, **81**, 1970–1984.

McAney, K., O'Mahony, C., Kelleher, C., Taylor, A. & Biggane, S. (2013) *The Lesser Horseshoe Bat in Ireland: Surveys by The Vincent Wildlife Trust*. Irish Naturalists' Journal, Belfast, Northern Ireland.

Morgan, B.J.T. (1992) *Analysis of Quantal Response Data*. Chapman and Hall, London, England.

Ransome, R.D. & McOwat, T.P. (1994) Birth timing and population changes in greater horseshoe bat colonies (Rhinolophus ferrumequinum) are synchronised by climatic temperature. *Zoological Journal of the Linnean Society*, **112**, 337–351.

Roche, N., Langton, S. & Aughney, T. (2012) *Lesser Horseshoe Bat: Population, Trends and Threats 1986 to 2012*. Unpublished, Bat Conservation Ireland, Cavan, Ireland.

Sims, M., Elston, D.A., Harris, M.P. & Wanless, S. (2006) Incorporating variance uncertainty into a power analysis of monitoring designs. *Journal of Agricultural, Biological and Environmental Statistics*, **12**, 236–249.