Development of a Car-Based Bat Monitoring Protocol for the Republic of Ireland

Irish Wildlife Manuals No. 19

AN ROINN COMHSHAOIL, OIDHREACHTA AGUS RIALTAIS ÁITIÚIL
DEPARTMENT OF THE ENVIRONMENT, HERITAGE AND LOCAL GOVERNMENT

An Chomhairle Oidhreachta
The Heritage Council

Development of a Car-Based Bat Monitoring Protocol for the Republic of Ireland

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Citation:
Roche, N, Catto, C., Langton, S., Aughney, T. and **Russ, J. (2005)** Development of a Car-Based Bat Monitoring Protocol for the Republic of Ireland. *Irish Wildlife Manuals*, No. 19. National Parks and Wildlife Service, Department of Environment, Heritage and Local Government, Dublin, Ireland.

Cover photo: Irish landscape by Con Brogan

Irish Wildlife Manuals Series Editor: F. Marnell

ISSN 1393 – 6670

Contents

EXECUTIVE SUMMARY

Introduction

Monitoring trends of bat populations is an essential component of bat conservation and addresses obligations under the EUROBATS Agreement and the Habitats Directive. At present in Ireland, there is little available bat population trend data.

In 2003 The Heritage Council asked the Bat Conservation Trust (BCT) UK to develop and evaluate a new bat detector-based monitoing project for the Republic of Ireland. In 2004, Bat Conservation Ireland, in partnership with The Bat Conservation Trust, administered the second year of the pilot monitoring project, under the direction of The Heritage Council and National Parks and Wildlife Service.

Targets for monitoring sensitivity are based on IUCN-developed criteria for measured population declines:

- ‘Amber’ Alert – 25-49% decline after 25 years
- ‘Red Alert’ – 50% (or greater) decline after 25 years

Bats are considered sensitive indicators of the health of the wider environment and their population trends will reflect changes in climate, water quality and agricultural practices. Publicity generated by the project will raise awareness of bats among the general public and emphasise the importance Ireland plays in safeguarding European populations of Leisler’s bat.

Methods

A sampling based strategy was devised in 2003 by the BCT that minimises bias and maximises precision, and from which trends for bat populations can be inferred. Surveyors were provided with a randomly generated 30km^2 square and asked to devise a 58-mile (93km) survey route consisting of 20 monitoring transects of 1 mile (1.609km) length, spaced at 2 miles (3.2km) apart.

A standardised method was developed together with standardised recording sheets and workshops were carried out to train surveyors.

Surveyors gathered data with time expansion bat detectors. Bat echolocation calls were recorded onto minidiscs and species were identified post-survey by sonographic analysis.

Statistical analyses of Power were carried out based on the data gathered in 2003 and 2004 to determine which species could be monitored with the method and whether ‘Amber’ and ‘Red’ Alert targets could be met.

Additional examinations were carried out to determine the kind of data that will be made available on a yearly basis and that can contribute to our knowledge of the activity and distribution of bats in Ireland.

Results
In July 2004, 16 survey routes were surveyed and 15 survey routes were surveyed in August. This represents a total coverage of 998km of monitoring transects and over 120 hours of surveyor time.

Full datasets were available for analysis from 13 squares in July and 13 in August.

2033 bats calls were recorded to minidisc.

The mean encounter rate (per km) for each species/species group were: common pipistrelle (*Pipistrellus pipistrellus*) = 13, soprano pipistrelle (*P. pygmaeus*) = 4.7, Leisler's bat (*Nyctalus leisleri*) = 3.5 and *Myotis* sp = 0.3.

Encounter rates of all species were generally higher, although not significantly higher, in August than in July. Temperatures recorded by surveyors at the start of each night's survey work were significantly higher in August compared with July.

Soprano pipistrelles were recorded at lower levels than common pipistrelles throughout the country, excepting some survey squares north and west of the Shannon.

Graphical comparisons of Leisler's activity levels in different squares around the country showed that there may be some inland migration of Leisler's bats in August but further data and investigations need to be carried out to confirm this.

Comparison of bat encounter rates in 2003 and 2004 showed a significantly higher encounter rate among all species in 2004. This can probably be explained by a later start time in 2004 (45 minutes after sunset, compared with 30 minutes after sunset in 2003) and surveying earlier in the season 2004.

Power analysis demonstrated that Red Alert targets for common pipistrelles, soprano pipistrelles and Leisler's bats could be met after 11, 11, and 14 years monitoring, respectively, if 10 squares (each with 20 transects) are surveyed twice annually. If 15 squares are surveyed twice annually, Amber alert targets can be met for common pipistrelles within 20 years of monitoring. Investigations using Power analysis were also carried out to determine the number of year's monitoring required for different numbers of squares, different numbers of transects in each square and different numbers of repeats.

Power analysis could not be carried out on *Myotis* bats because the encounter rate was too low.

Ten other species of mammal, one amphibian and three bird species were encountered during the survey in 2004.

Recommendations
A list of recommendations has been made for the programme development.

INTRODUCTION

In 2003 The Bat Conservation Trust UK (BCT) develop a monitoring programme for certain species of bat in the Republic of Ireland, with grant funding from The Heritage Council. The results of the initial pilot in 2003 were presented in early 2004 (Catto *et al*. 2004). In 2004, Bat Conservation Ireland (BCIreland), in partnership with BCT, were funded by The Heritage Council and National Parks and Wildlife Service (NPWS) to co-ordinate a second year of the pilot monitoring project. This report presents

- the results of the second year's monitoring
- comparisons of data from 2003 and 2004
- a review of changes that were made to methodology in 2004
- and recommendations for the future monitoring of bats in Ireland.

Why Monitor Ireland's Bats?

Irish bats are protected under domestic 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 Habitats Directive (92/43/EEC) lists all Irish bat species in Annex IV and one Irish species, the lesser horseshoe bat (*Rhinolophus hipposideros*), in Annex II. Annex II includes animal species of community interest whose conservation requires the designation of Special Areas of Conservation (SACs) because they are, for example, endangered, rare, vulnerable or endemic. Annex IV includes various species that require strict protection.

Ireland is also signatory to a number of conservation agreements pertaining to bats such as the Bern and Bonn Conventions. The European Bats Agreement (EUROBATS), is an agreement under the Bonn Convention and Ireland is one of the 30 signatories. The Agreement has an Action Plan with priorities for implementation. Devising strategies for monitoring of populations of selected bat species in Europe is among the resolutions of Eurobats.

Two Irish species, the lesser horseshoe bat and the Leisler's bat (*Nyctalus leisleri*), are assigned IUCN threat categories by Hutson *et al.* (2000) (VU A2c and LR: nt, respectively). VU A2c indicates that the lesser horseshoe bat population in Ireland is vulnerable to decline and such declines may be predicted for the future if there is a decline in occupancy, extent of occurrence or quality of habitat. Ireland holds important European populations of Leisler's bat (Stebbings, 1988) which is categorised as lower risk, near threatened. Whilde (1993) in the Irish Red Data Book of vertebrates listed all Irish populations of bats (those species that were known to occur in Ireland at the time) as Internationally Important.

There has been an increase in levels of knowledge of Irish bats in the past 20 years, mainly due to increased numbers of researchers and bat workers. Despite high levels of legal protection for all species, however, there has been no systematic monitoring of any species apart from the lesser horseshoe bat. This pilot car-based bat monitoring scheme will help to redress the imbalance, ensure countrywide coverage and simultaneous monitoring of a number of species including the IUCN listed Leisler's bat.

Definite conclusions from a monitoring project based on the road network can only be made in relation to roadside habitats. Inferences from the roadside monitoring to wider bat populations can be made but are based on the assumption that population trend data collected from the roadside will mirror that of the wider population. Further work may be needed before extrapolating to other habitats.

Red and Amber Alerts

There are no precise biological definitions of when a population becomes vulnerable to extinction but the British Trust for Ornithology (BTO) has produced Alert levels based on IUCN-developed criteria for measured population declines. Species are considered of high conservation priority (Red Alert) if their population has declined by 50% or greater over 25 years and of medium conservation priority (Amber Alert) if their populations have declined by 25-49% over 25 years (Marchant *et al*., 1997). These Alerts are based on evidence of declines that have already occurred but if Alerts are *predicted* to occur based on existing rates of decline in a shorter time period then the species should be given the relevant Alert status e.g. if a species has declined annually by 2.73% over a 10-year period then it is predicted to decline by 50% over 25 years and should be given Red

Alert status after 10 years. Monitoring data should be of sufficient statistical sensitivity to meet (and better, if possible) these Alert levels.

The Importance of Ireland's Road Network for Bats

Ireland's small roads, most of which are lined with trees and hedgerows, consitute a major network of connectivity in the landscape. Most Irish bat species need to fly along linear landscape features when commuting from roost to foraging site and vice versa. In addition, hedgerow and tree-line habitats lining many roads provides a source of insect prey for bats in flight. Bat activity at other habitats lining roadsides – such as rivers, lakes, bogs and forests could also potentially be examined using data from this monitoring scheme.

Road developments can also potentially impact negatively on bat biodiversity. Data collected on this programme, when analysed in conjunction with roadside habitat data, will help allow informed decisions on future road network developments leading to lessened environmental impacts. Data collected from this monitoring scheme also have potential applications on a national and regional basis.

Carrying out night-time survey work along roads provides an additional opportunity to survey for other vertebrates, many species of which traverse the road network or forage along it at night.

CAR-BASED BAT MONITORING PROTOCOL

What is a car-based bat monitoring scheme?

This protocol is a relatively newly devised method of monitoring bats while driving. Monitoring is carried out using a bat detector which picks up the ultrasonic (high pitched) echolocation calls made by bats and converts them to a frequency audible to the human ear. For this scheme, time expansion detectors are used which essentially make short recordings of a broad range of ultrasound and replay the sounds at a slower speed. The monitoring is carried out along known routes, at a specific time of year, while driving at a standard speed. All sounds are recorded for analysis at a later stage.

Overall Aims of Pilot Car-Based Bat Monitoring

1. Provide a method of monitoring that can be implemented by relatively few surveyors and that does not require highly trained individuals.
2. Provide a method of data collection that is
    - objective
    - easily repeatable
    - cost effective.
3. Ensure sufficient data is collected that will allow early recognition of Red Alert declines in certain Irish bat species' populations.
4. Assess feasibility of recording other non-bat wildlife on survey.
5. An additional aim of the pilot in 2004 was to determine the feasibility of using Duet detectors (set to heterodyne mode) to monitor for lesser horseshoe bats.

Future Aims

- To extrapolate information on bat activity within survey squares to determine 'hotspot' areas, and/or areas of high bat diversity.
- To correlate information on bat activity with habitat availability to determine important habitats for foraging bats in Ireland.
- To determine population trends and allow early detection of population declines.

2004 BAT MONITORING SCHEME

The Aims of this Report

This second annual report is an essential tool to disseminate the results to volunteers who diligently mapped survey routes and carried out survey work for many hours at night time. In addition, the yearly report will aim to provide a reference source for policy and decision makers. This second yearly report will demonstrate the feasibility of using car monitoring to determine the status of certain Irish bat populations, compare the limited data available from 2003 with that of 2004 and highlight survey squares where particularly high bat activity was recorded. Since this is only the second year of monitoring and certain survey methods differed between 2003 and 2004, trends in population cannot yet be determined. However, Power analysis results confirm that this method is sensitive enought to be used in the long-term to pick up Red Alert population declines in certain species.

In addition, some new possibilities for further investigation of the data will be given an initial examination here – such as the ratios of relative common to soprano pipistrelle bat activity and variations in relative activity of different species around the country.

Identification of Sites of Importance

For the lesser horseshoe bat, the only Irish bat species listed in Annex II of the EU Habitats Directive, criteria for determining the importance of roosts has been defined, mainly for the purposes of SAC designation. For the other Irish bat species, populations of which are not so well known, or for assessments of bat foraging areas there are, as-yet, no defined levels that can be used as a reference to indicate whether activity levels are particularly high (or low). An initial assessment of each survey square has been made using mean bat encounters from the 2004 data but, with more monitoring data becoming available year after year, criteria defining sites of importance are likely to become better established.

Interpretation of Bat Encounter Data

Following the discovery of echolocation in the 1950s and the subsequent development of bat detectors, there has been a vastly increased level of investigation of bat species worldwide. Bat detectors are a non-invasive method of establishing presence and absence of bats in a certain area and depending on detector type and/or observer skill, can allow the identification of the species present. The present monitoring system, which requires volunteers to drive a set route at 24km per hour while recording bats using a time expansion detector, results in the collection of bat sounds which are recorded to minidisc and subsequently analysed using sonogram analysis software. From this, the bats present on a particular transect can be identified to species level (in most cases) and the number of encounters with each species per kilometre (or unit time) can also be established. This method of data collection allows for cross comparisons in encounter rates between survey dates, between years and between survey areas. Inter-species comparisons are restricted to those species that emit similar calls at similar loudness. For example – the encounter rate of Leisler's bats cannot be directly compared with those of common pipistrelles since Leisler's bats are much louder and can be detected from a further distance compared with pipistrelles. Also, trends can be extrapolated over time to determine whether populations are in decline. However, it is possible that a single bat could be recorded more than once as the vehicle passes during a transect survey. For this reason, to consider encounter rates per kilometre as a direct indication of individual bats per kilometre would probably be inaccurate and overestimate bat numbers. Further work on modelling the relationship between bat encounter rate and number of individual bats will have to be carried out. Encounter rates per km are used to indicate bat activity levels in the results section of the present report.

Factors Causing Variation in Bat Activity

Many factors may lead to variation in bat activity, these include:

- ***Air temperature***. Insect prey availability drops in low temperatures.
- ***Wind speed and direction***. Prey insects swarm to the lee of windward (which could determine which side of a road the bat will fly along) and bats will not fly in high wind speeds.
- ***Roost occurrence along a transect***. Buildings tend to be situated along roads and bat roosts are often found in buildings.
- ***Habitat availability***. This may not be a source of major year to year variation but overall abundance of different habitat types and, possibly, trends in hedgerow maintenance may affect bat abundance in different areas/squares.
- ***Lighting***. White street lighting can attract insects and subsequently some species of bat, while causing a decline in others.
- ***Timing of survey work***.

Weather in July-August 2004

July and August are generally the hottest two months of the year in Ireland, with average air temperature for the entire country in the region of 15°C. July 2004 temperatures were generally similar to or slightly lower than the local average (by less than 1˚C) at different weather stations around the country. August temperatures generally rose to slightly higher than average (by approximately 1˚C). Rainfall patterns were not consistently similar countrywide. Along the eastern part of the country (Kilkenny and Dublin) rainfall was lower than average in July but much higher than average in August. A similar pattern was observed in Cork. Midlands, western, border and northern counties showed a much more variable rainfall pattern (weather data derived from the Met Eireann website www.meteireann.ie).

METHODS USED

This car-based bat monitoring method was designed by The BCT in 2003. The BCT is now planning to set up a similar scheme in the UK 'The Bats and Roadside Mammals Project' which is due to begin in 2005. To-date much bat monitoring work has been done in other countries by foot-based trained volunteers (e.g. the UK National Bat Monitoring Scheme) but in Ireland, a paucity of trained bat workers means that such monitoring work would not be feasible. The car-based method ensures that large areas can be covered in one night and the use of a time-expansion detector means that volunteers do not need to be highly skilled in bat identification to collect the data accurately.

Training of surveyors was carried out in July 2003 by the BCT and in June 2004 by BCIreland. In 2003 and 2004 17 volunteers, which included members of Bat Conservation Ireland and staff of NPWS and The Heritage Council, along with field work partners, mapped out a route within a defined 30km ***Survey Square***. The route covered 20 x 1.609km (1 mile) ***Monitoring Transects*** each of which was separated by a minimum distance of 3.2km (2 miles). Surveyors were then asked to carry out the survey on two dates, one in July (S1) and one in August (S2). To survey the route each of the 1.609km transects was driven at 24km (15 miles) per hour (at night) while continuously recording from a time expansion bat detector to minidisc.

Minidiscs were forwarded to Bat Conservation Ireland for analysis. Prior to analysis taking place, Bat Conservation Ireland was trained by Jon Russ (BCT) to carry out the sound analysis.

Each track was downloaded to Bat Sound and calls were identified to species level where possible. Species that can be identified accurately using this method are the common, soprano and Nathusius' pipistrelles (*Pipistrellus pipistrellus, P. pygmaeus, P. nathusii*). Leisler's bats, a low frequency echolocating species, can also be easily identified using this method. Occasional calls of *Myotis* bats were recorded but these are noted as *Myotis* spp. since they could belong to one of a number of similar species – Daubenton's, whiskered, Natterer's or the recently discovered Brandt's bat (*Myotis daubentonii, M. mystacinus, M. nattereri, M. brandtii*). Pipistrelle calls with a peak in echolocation between 48kHz and 52kHz were recorded as 'Pipistrelle unknown' because they could be either common or soprano pipistrelles.

A number of randomly selected .wav files were forwarded to The BCT for analysis for quality control purposes. In addition, a number of randomly selected .wav files from the 2003 surveys were analysed by Bat Conservation Ireland and results compared with those derived in 2003 by The BCT, for quality control purposes.

Detailed methodology is given in Appendix I.

Lesser horseshoe bats, *Rhinolophus hipposideros*

For two of the western survey squares, surveyors were equipped with an additional bat detector in 2004. At V96 and R28, both of which are situated within prime lesser horseshoe bat territory, surveyors were given a Stag Electronics Duet bat detector and asked to attach it to the detector clamp. This detector was set to the correct frequency for lesser horseshoe bats (approx. 110kHz) and sounds from this detector were fed through a car cassette kit so the surveyors could listen to sounds produced by the detector while driving. Surveyors were asked to record any lesser horseshoe bats encountered during and in-between monitoring transects.

RESULTS

Squares Covered in 2003

Seven volunteers participated in the 2003 pilot scheme (with field work partners) and utilisable data was collected from seven survey squares. Utilisable data was subsequently gathered from 2 repeat survey squares. Survey work in 2003 was carried out from mid to late August and transect coverage began 30 minutes after sundown.

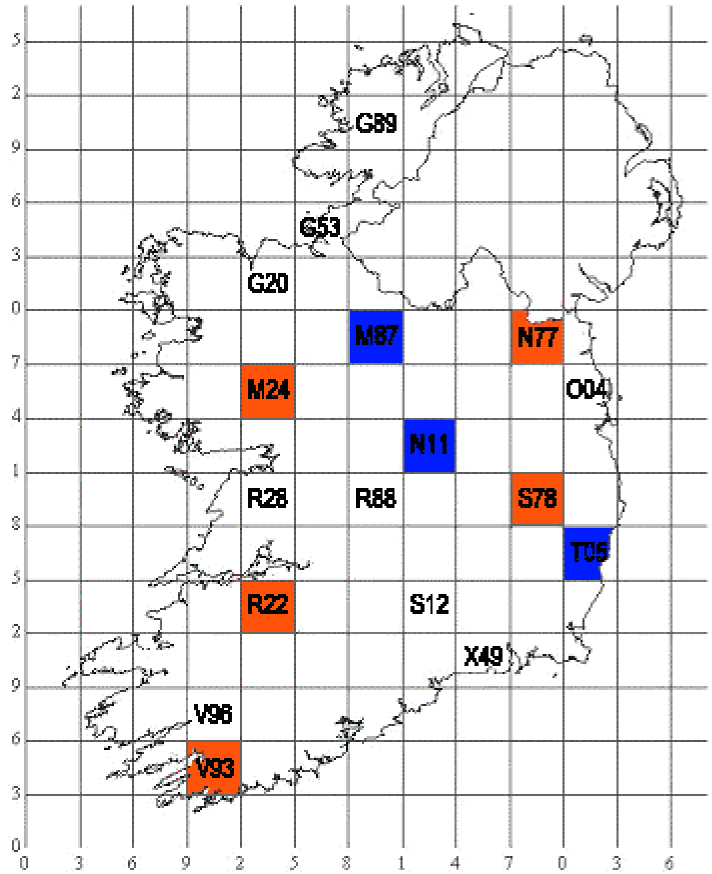


Figure 1. Squares in which surveys were carried out in 2003. Red indicates those 30km² squares in which surveys were repeated. Blue squares were surveyed once. Un-coloured squares with identifying numbers indicate additional squares that were surveyed in 2004.

Squares Covered in 2004

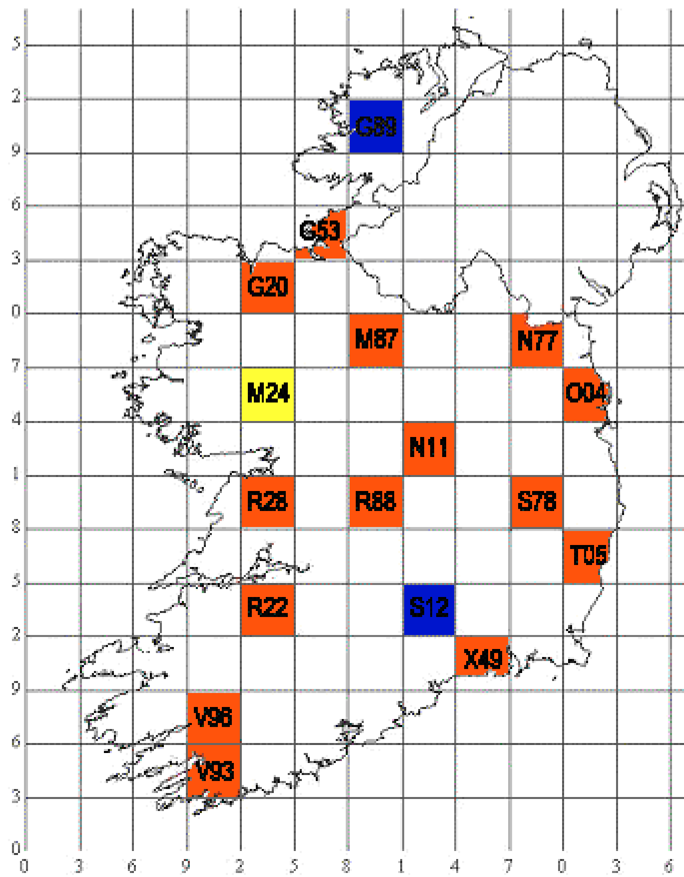


Figure 2. Squares in which surveys were carried out in 2004. Red indicates those 30km² squares in which surveys were repeated. Blue squares were surveyed once in July and the square indicated in yellow was surveyed once in August.

Survey work in 2004 was carried out from mid-July to end-July and a repeat survey was carried out from early to mid-August. Transect coverage began 45 minutes after sundown.

A total of 17 survey routes were surveyed. Fourteen of these were repeated (31 night's field work). This represents 998 km of monitoring transects driven and approximately 120hrs of surveyor time.

Limited data (e.g. data from just a few transects, or data for single species) were available from recordings made during 4 survey routes. This was mainly due to failure of certain pieces of equipment such as leads or bat detectors. The entire dataset from one survey route (in August) was considered unsuitable for analysis, also due to equipment failure. Therefore, a full dataset was available for analysis from 13 survey routes in July and 13 survey routes in August, 10 of which were repeat surveys. Squares that were surveyed in 2004 cover much of the Republic and stretch from the extreme south to Donegal. Midlands, western, eastern and border counties are also covered.

In total, 2033 bat encounters were recorded during the July and August 2004 surveys, from 576 independent monitoring transects. Note that 2033 bat encounters does not necessarily equate to 2033 different bats since bats may be recorded more than once during a transect and/or recorded in July and again in August.

The mean time to complete a survey route was 233mins (3 hours 53 minutes), (SD = 32.75, Min = 175, Max = 279), compared with 232.4mins in

2003, and the mean time to complete a monitoring transect varied between survey routes (see Appendix I). On average it took 273 seconds to complete each monitoring transect (compared to 268.54 in 2003). As the time expansion system only samples 1/11 of the time, this meant there was an average total sampling time of 24.81 seconds per monitoring transect. Also, for every monitoring transect covered 0.146 km (0.091 miles) were actually surveyed (i.e. 1/11th of the distance).

Dataset generated

The data shown in Table 1 below illustrates the overall number of times a bat call was recorded to minidisc during the 2004 surveys. There were sufficient encounters of common pipistrelles (*Pipistrellus pipistrellus*), soprano pipistrelles (*P.* pygmaeus) and Leisler's bats (*Nyctalus leisleri*) for analysis but not for any other species/species groups.

Table 1: Raw bat encounter data, not corrected to encounters per km, Pilot Car-based Bat Monitoring Scheme 2004. Average number of bats per transect reflects the average number of bat encounters observed during each 1.609km transect travelled. Total Number of Transects (N)=577 for pipistrelle, *Myotis* spp. and total numbers; for Leislers N=597. Note that the detector records for just $1/11^{th}$ of the time spent surveying so to determine the number of bat encounters per km this must be divided by 0.146 (the total distance sampled for each 1.609km transect).

	Common pipistrelle	**Soprano pipistrelle**	**Pipistrelle unidentified**	**Myotis spp.**	**Leisler's bat**	**Total Bats**
Average no. per transect	3.803	1.387	0.885	0.100	1.021	7.229
Min per transect	0	0	0	0	0	0
Max per transect	21	13	8	2	11	27
SD	2.8	1.5	0.9	0.3	1.3	4.3
TOTAL	**1061**	**387**	**247**	**28**	**295**	**2033**

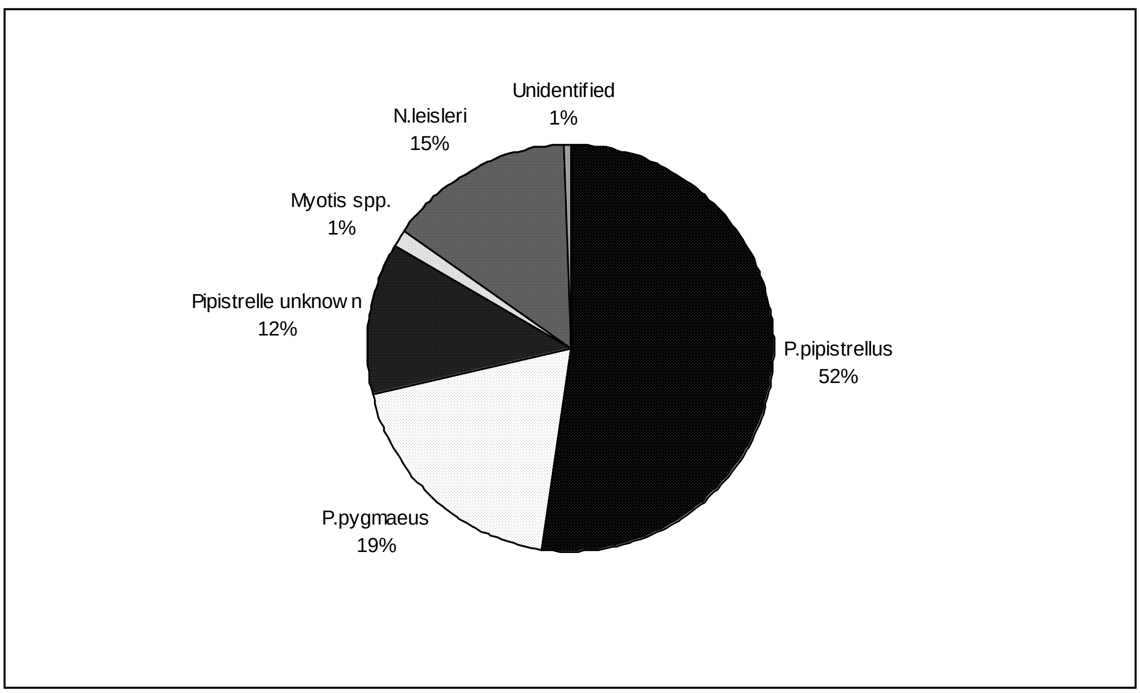


Figure 3: Proportion of species encountered during 2004 survey. 'Unidentified' refers to a number of calls that could definitely be ascribed to bats but could not be identified to species or species group. Bat social calls were recorded but are not included in the above pie chart or in analysis, excepting those of Leisler's bats which are unlikely to be mistaken for social calls of other species.

The average number of bat encounters per transect can be corrected to provide a number of bats encountered per km.

Since the average time taken to survey each transect varied between survey routes (see Appendix II, Table A3), the following graph was plotted to determine the relationship between number of bat encounters per km and number of bat encounters per minute. Pearson's r correlation coefficient for Figure 4, common pipistrelle encounters per minute and encounters per km, is 0.993. This indicates a near perfect correlation between the two variables.

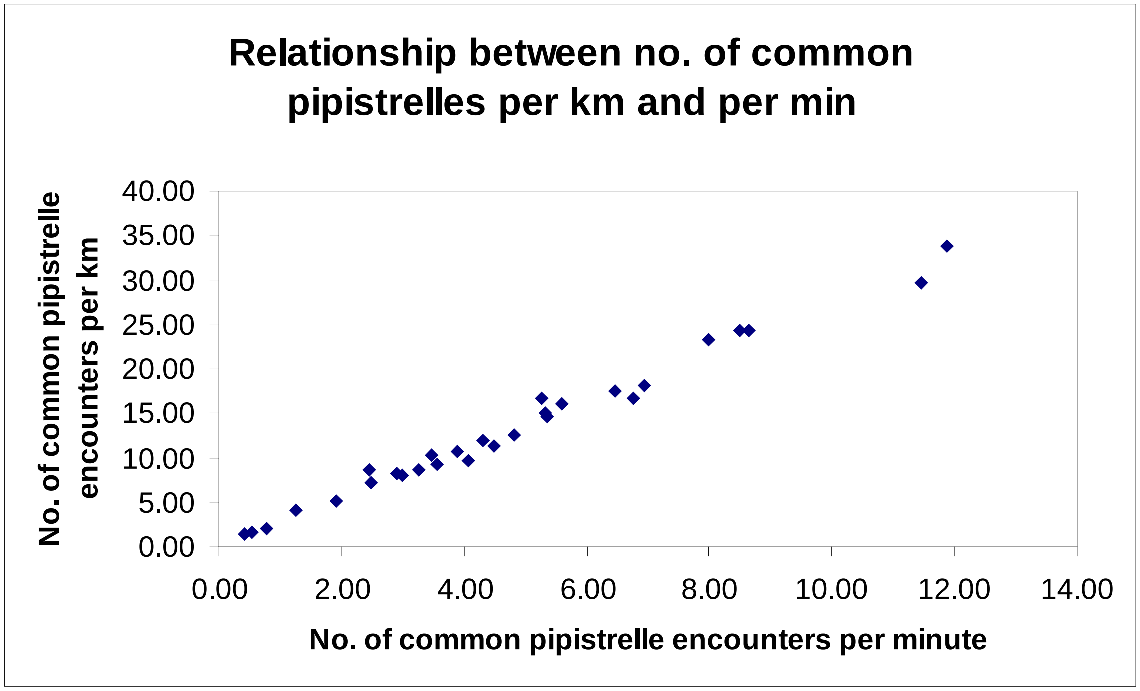


Figure 4: Relationship between the number of encounters of common pipistrelles per minute and per kilometre, all survey squares, 2004.

Similar graphs (and Pearson's r coefficients) illustrating a high correlation between number of encounters per minute and encounters per km can be plotted for soprano pipistrelles and Leisler's bats. However, the effect of different travelling speeds on the likelihood of detecting bats during monitoring transects cannot be accounted for by determining simply the number of encounters per minute or number of encounters per kilometre.

Numbers of Bats per Kilometre

For the purposes of the present report, the effects of driving speed on bat detectability are unknown so cannot be determined. Results are shown mainly as number of encounters per km – corrected to allow for the detector sampling for 1/11th of the distance travelled – irrespective of the time taken to complete transects. Overall average numbers of bat encounters per kilometre are shown in Table 2 below. Common pipistrelles were the most active bat species along many of the routes, except G20-2, G53-1 and M24-2 where soprano pipistrelles were recorded more frequently. Leisler's bats were the third most frequently recorded species. *Myotis* bat species were encountered relatively rarely. The maximum number of *Myotis* bats encountered on any single monitoring transect was two (see Table 1 above).

Table 2: Average number of bat encounters per kilometre for each survey square in 2004 (number of transects (n) =20 for each survey square unless otherwise stated). Ppip = *Pipistrellus pipistrellus*, Ppyg = *Pipistrellus pygmaeus*, pipun = Unidentified pipistrelles echolocating between 48 and 52kHz, Nl = *Nyctalus leisleri,* My = *Myotis* spp., Total = total number of passes for all bat species. Means derived from total number of encounters divided by total number of km sampled by the time expansion detector, i.e. corrected for sampling 1/11th of the time.

Square	Ppip/km	Ppyg/km	pipun/km	Nl/km	My/km	Total/km
G20-1[1]	4.11	1.37	3.08	2.05	0.00	10.96
G20-2	1.37	5.14	0.34	1.03	1.37	9.25
G53-1	2.05	9.25	4.11	1.37	0.34	16.78
G89-1	1.71	1.71	1.37	0.34	0.00	5.14
M24-2	8.56	16.78	5.14	3.42	0.34	34.93
M87-1 (n=6)	7.99	1.14	1.14	0.00	0.00	10.27
M87-2	5.14	4.45	1.37	7.88	0.00	18.84
N11-1	14.73	3.42	6.85	2.40	0.00	28.08
N11-2	24.32	12.67	5.48	2.74	0.00	45.55
N77-1	11.99	3.77	2.74	3.77	0.00	22.26
N77-2	17.47	2.40	0.68	6.85	0.68	28.42
O04-1	18.15	1.37	4.79	3.77	0.00	28.08
O04-2	9.25	0.68	2.05	2.40	0.00	14.38
R22-1	23.29	5.14	3.77	2.74	0.34	35.96
R22-2	16.78	8.90	3.77	1.37	1.37	32.53
R28-1	8.22	1.03	0.34	5.14	0.00	14.73
R28-2				4.79		
R88-1	8.56	3.77	1.71	0.34	0.00	14.38
R88-2	12.67	3.08	0.68	5.14	0.00	21.58
S12-1	9.59	2.05	2.05	2.40	0.68	17.12
S78-1 (n=12)	29.68	9.13	6.85	2.85	0.00	48.52
S78-2	16.78	7.88	3.77	6.16	0.68	35.62
T05-1	11.30	4.11	4.45	2.05	0.34	22.26
T05-2	24.32	4.79	4.11	9.59	0.34	42.81
V93-1 (n=19)	10.81	2.88	1.08	7.57	0.00	22.71
V93-2	33.90	6.16	6.85	5.48	0.34	52.74
V96-1	15.07	5.14	4.79	2.74	0.00	28.08
V96-2	16.10	3.77	1.37	0.68	1.37	23.63
X49-1	10.27	3.77	2.74	4.11	1.03	21.92
X49-2	7.19	1.37	0.68	1.37	0.34	10.96
Overall Mean	**13.0**	**4.7**	**3.0**	**3.5**	**0.3**	**24.8**

[1] G20 - 1 indicates the square and refers to the first or second survey (1 = Survey 1 July, 2 = Survey 2 August).

Common pipistrelle, *Pipistrellus pipistrellus*, in 2004

The overall average number of *Pipistrellus pipistrellus* encounters per km was 11.4 during the July 2004 (S1) survey, compared with 14.9 for the August (S2) 2004 survey. The difference in encounter rates between the two months is not significant (95%) when a Wilcoxon signed rank test (non-parametric) is carried out on the data (for the squares where surveys were repeated). The overall average number of common pipistrelle encounters per km for both months was 13.0, see Table 2 above. Common pipistrelles were the most commonly encountered species during the monitoring scheme in 2004.

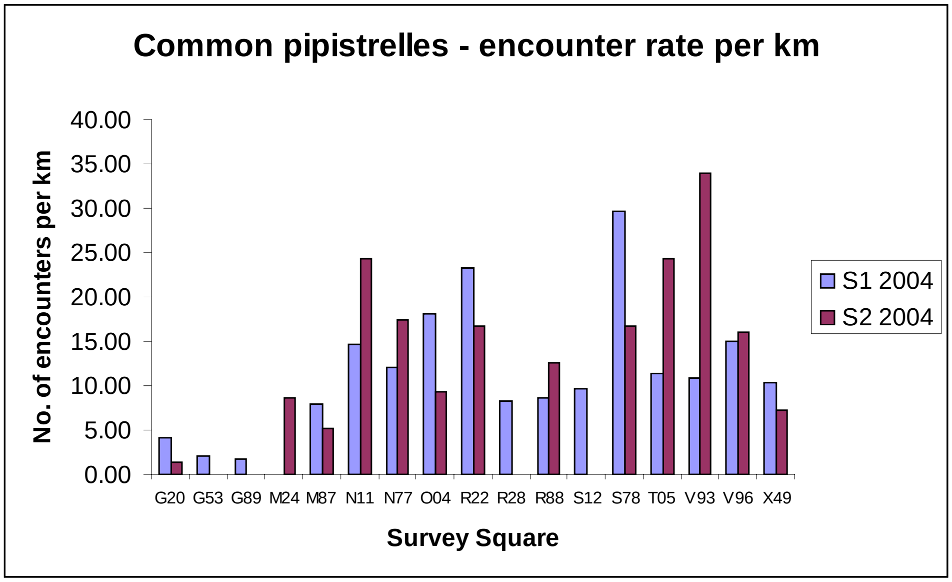


Figure 5: Average number of common pipistrelles, *Pipistrellus pipistrellus*, encountered (i.e. picked up on the detector and recorded to the minidisc) per kilometre during July (S1) and August (S2) in 2004.

Particularly high encounter rates were observed in S78 (S1) and V93 (S2). Encounter rates at G20, G53 and G89 were generally very low compared with other survey squares.

Figure 6 provides an indication of particularly high encounter rate survey squares and relative changes in encounter rates between July and August for common pipistrelles. In addition, this mapping exercise can also be considered a cursory examination of relative countrywide activity distribution for the species. In general, Figure 6 indicates somewhat higher encounter rates of common pipistrelles in the south east of the country compared with the north west (or east and south of the Shannon compared with west and north of the Shannon).

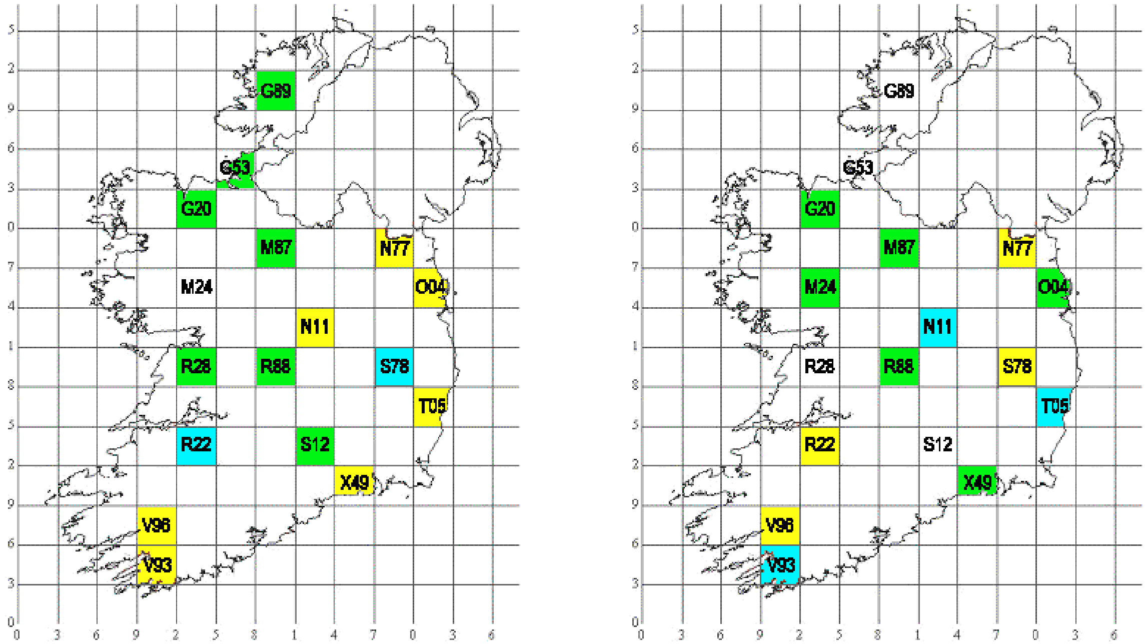


Figure 6: Survey blocks colour coded according to **common pipistrelle** encounter rates (per km). Map on left represents data from July 2004 and map on right represents data from August 2004. Green indicates the number of common pipistrelle encounters was lower than 10/km. Yellow indicates that the number of common pipistrelle encounters was above 10/km but lower than 20/km. Blue indicates that the number of common pipistrelle encounters was over 20/km. The overall average rate of common pipistrelle encounters for 2004 was 13.1/km. Squares are not highlighted if no data is available.

Comparing 2003 and 2004 - *Pipistrellus pipistrellus*

Table 3: Dates of surveys carried out in 2003 compared with dates of S2 2004, along with average no. of *Pipistrellus pipistrellus* encounters per km (in brackets) for each square.

Square	2004 Survey 2	2003 Survey 1	2003 Survey 2
M87	12-08-04 (5.14)	13-08-03 (14.73)	
N11	12-08-04 (24.32)	26-08-03 (19.86)	
N77	14-08-04 (17.47)	24-08-03 (4.11)	31-08-03 (9.93)
R22	14-08-04 (16.78)	22-08-03 (2.05)	
S78	28-07-04 (16.78)		24-08-03 (13.01)
T05	13-08-04 (24.32)	12-08-03 (14.73)	
V93	13-08-04 (33.90)	18-08-03 (7.88)	28-08-03 (5.82)

Direct comparisons between the limited data available for 2003 and data from 2004 are hampered by differences in survey timing between years. In 2003, some surveys took place later in August, compared with mid-August (except S78 which took place in late July) in 2004. In addition, surveys began 30 minutes after sundown in 2003 while surveying began 45 minutes after sundown in 2004.

Figure 7 illustrates the difference between 2003 and 2004, in average number of common pipistrelle encounters per km for survey squares.

Consistently higher numbers of common pipistrelles were encountered during surveys in August 2004 compared with August 2003. Results of a Wilcoxon signed ranks test (non-parametric) showed a significant difference ($z=2.366$, $p=0.01$) in overall common pipistrelle encounter rate in 2003 and 2004 (comparison was made between the same squares in both years).

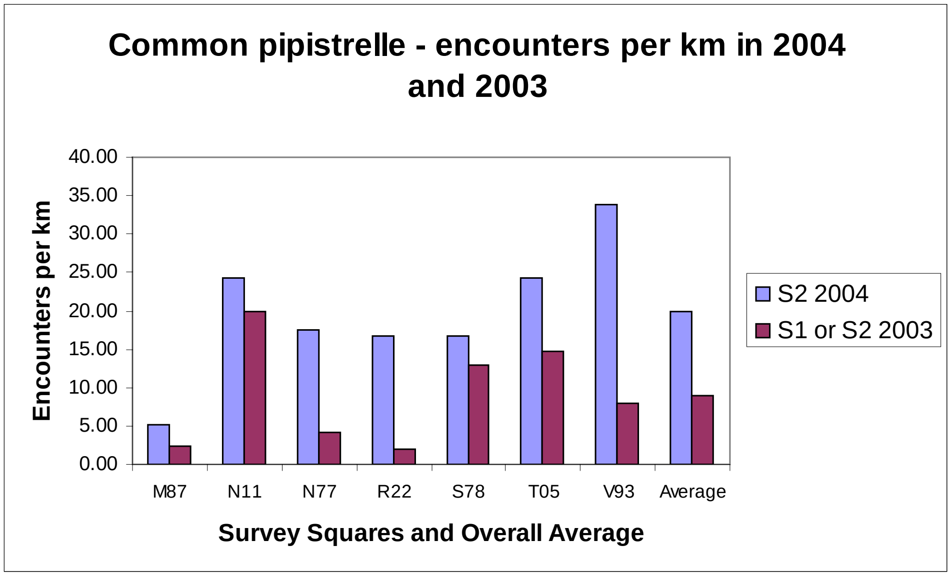


Figure 7: A comparison of average number of common pipistrelle, *Pipistrellus pipistrellus*, encounters per km between those squares surveyed in 2003 and Survey 2 (August) 2004. For 2003, S1 or S2 refers to the survey date most closely matching that of S2 of 2004 – see Table 3 above for details. Average shown for 2003 is derived from all survey squares, the average for 2004 is derived solely from the seven survey squares shown – to allow a direct comparison.

Soprano pipistrelle, *Pipistrellus pygmaeus*, in 2004

The overall mean number of *Pipistrellus pygmaeus* encounters per km for the July 2004 survey (Survey 1) is 3.7. The August (Survey 2) average is 6.0 encounters per km. The difference in encounter rates between the two months is not significant (95%) when a Wilcoxon signed rank test (non-parametric) is carried out on the data (for the 10 squares where surveys were repeated). The overall average for both months in 2004 is 4.7 passes per km, see Table 2 above.

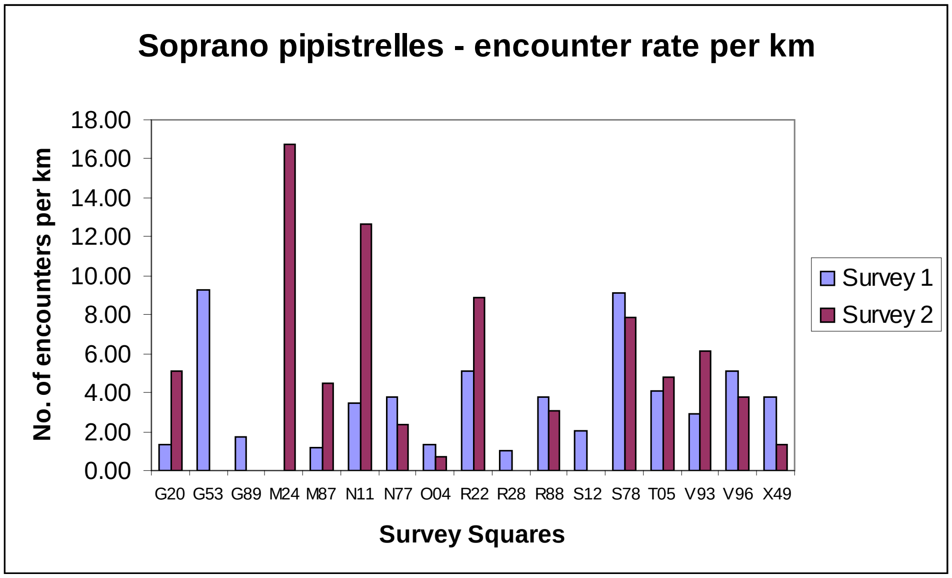


Figure 8: Average number of soprano pipistrelles, *Pipistrellus pygmaeus*, encountered (i.e. picked up on the detector and recorded to the minidisc) per kilometre during July (S1) and August (S2) in 2004.

Particularly high encounter rates of soprano pipistrelles were observed in M24 (S2) and N11 (S2). Low encounter rates were observed at a number of survey squares such as R28 (S1), M87 (S1 – n=6) and O04 (both S1 and S2).

Figure 9 provides an indication of particularly high encounter rate survey squares and relative changes in encounter rates between July and August for soprano pipistrelles. In addition, this mapping exercise can also be considered a cursory examination of relative countrywide activity distribution for the species.

No particular patterns of activity distribution of soprano pipistrelles can be derived from Figure 9. However, increased levels of soprano pipistrelle activity from July to August are illustrated by a higher number of yellow and blue squares for that month.

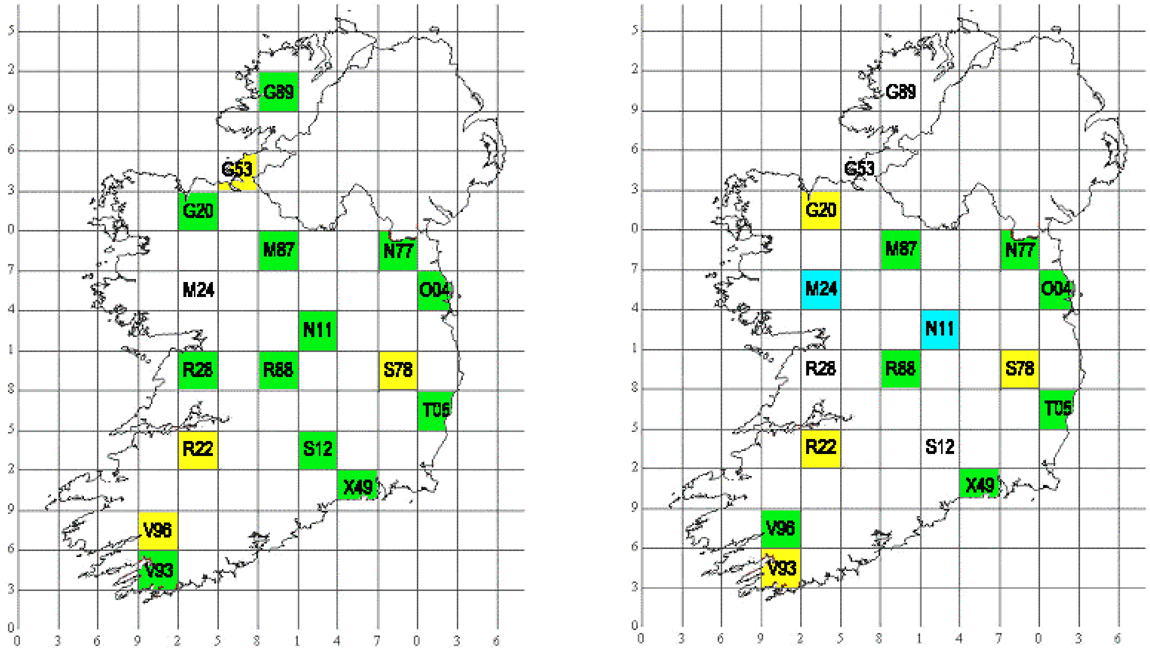


Figure 9. Survey blocks colour coded according to **soprano pipistrelle** encounter rates (per km). Map on left represents data from July 2004 and map on right represents data from August 2004. Green indicates the number of soprano pipistrelle encounters was below 5/km. Yellow indicates that the number of soprano pipistrelle encounters was greater than 5/km but lower than 10/km. Blue indicates that the number of soprano pipistrelle encounters was over 10/km. The overall average soprano pipistrelle encounter rate for 2004 was 4.76/km. Squares are not highlighted if no data is available.

Comparing 2003 and 2004 - *Pipistrellus pygmaeus*

Figure 10 illustrates the difference between 2003 and 2004, in average number of soprano pipistrelle encounters per km for survey squares.

Higher numbers of soprano pipistrelles were encountered during surveys in most squares in August 2004 compared with August 2003. Results of a Wilcoxon signed ranks paired test (non-parametric) showed a significant difference (z=2.366, p=0.02) in overall soprano pipistrelle encounter rate in 2003 and 2004 (comparison was made between the same squares in both years).

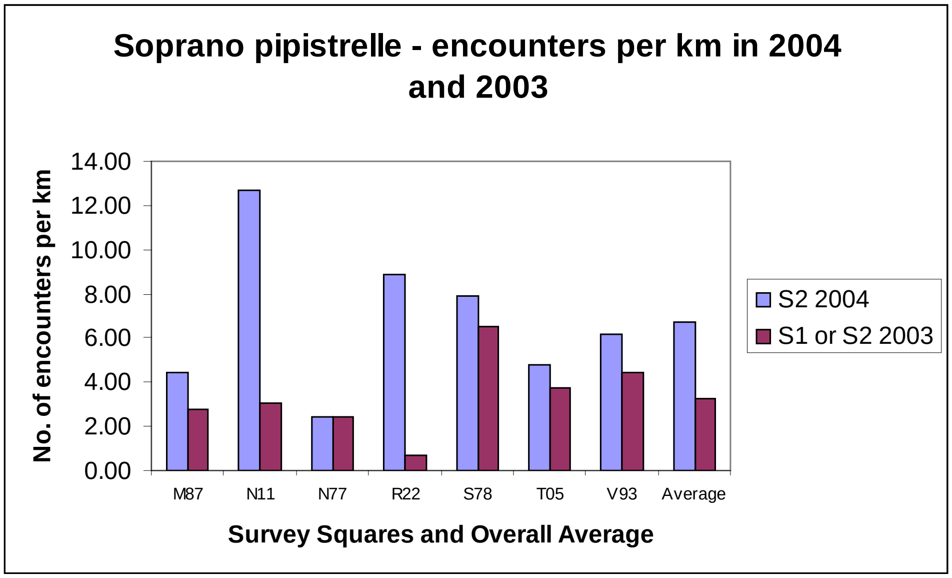


Figure 10: A comparison of average number of soprano pipistrelle, *Pipistrellus pygmaeus,* encounters per km between those squares surveyed in 2003 and Survey 2 (August) 2004. For 2003, S1 or S2 refers to the survey date most closely matching that of S2 of 2004 – see Table 3 above for details. Average shown for 2003 is derived from all survey squares, the average for 2004 is derived solely from the seven survey squares shown – to allow a direct comparison.

Ratio of common pipistrelle to soprano pipistrelle activity

Overall in 2004, much higher common pipistrelle activity (per km) was recorded compared with soprano pipistrelle activity (per km), see Figure 11 below. Note that making a direct comparison between encounter rates for these two species is based on the assumption that both produce echolocation calls that are equally detectable, which may not be strictly true. The common pipistrelle echolocates at a slightly lower average peak frequency – 45kHz – and this sound will not attenuate as quickly as a sound produced by a soprano pipistrelle at the higher frequency of 55kHz, so common pipistrelles may be more detectable. However, whatever bias may exist in detectability for the two species it is unlikely to vary across the country.

On average, 4.1 times the number of common pipistrelle encounters (per km) were recorded, compared with soprano pipistrelles. However, exceptionally high levels of soprano pipistrelle activity relative to common pipistrelle activity were observed in a number of north-western counties. Out of the five north-western survey squares (G20, G53, G89, M87, M24) – the ratio of common to soprano pipistrelle activity is, for five of the available datasets, less than 1.5 and in some squares (G53 July, G20 August and M24 August) soprano pipistrelle activity is actually much higher than common pipistrelle activity. A number of hypotheses may explain why soprano pipistrelles are relatively more active in the north west (e.g. competitive exclusion by common pipistrelles, increased occurrence of favoured habitats, influence of migration, weather effects) and these can be further investigated as more data becomes available.

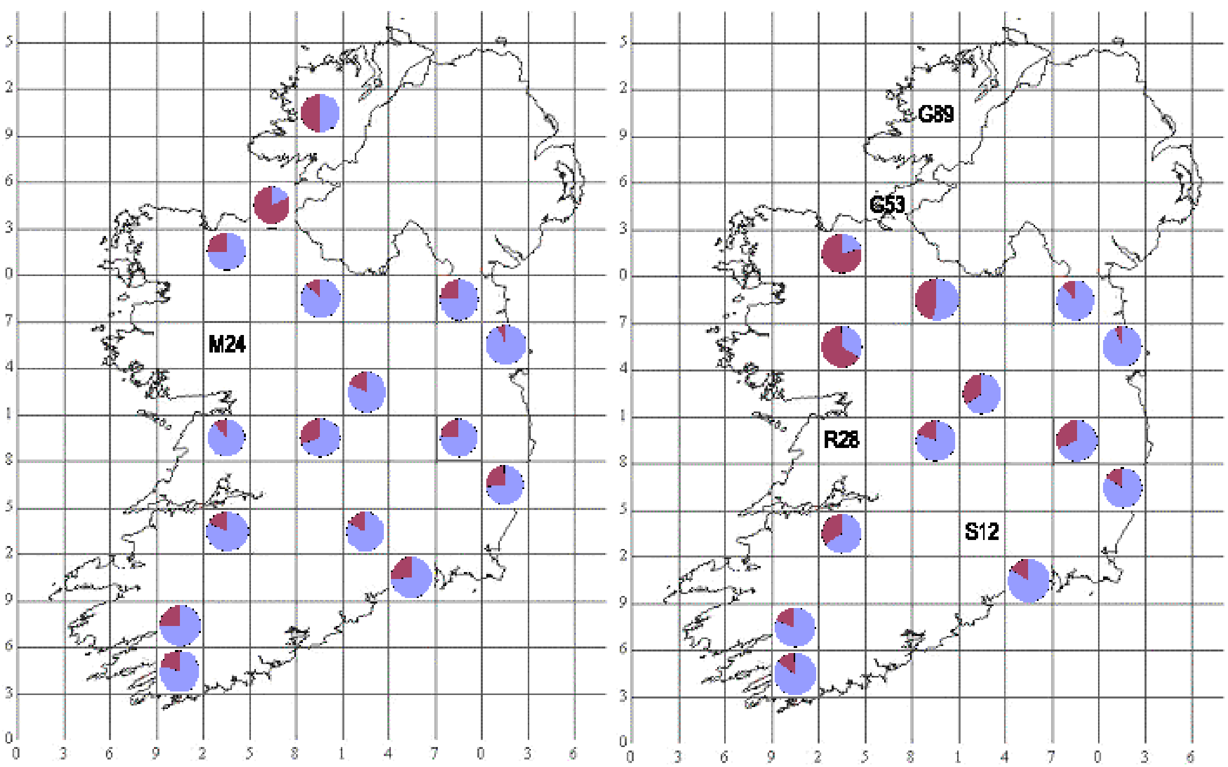


Figure 11: Pie charts illustrating relative encounter rates – per km – of common pipistrelles (blue) and soprano pipistrelles (burgundy) in July (map on left) and August (map on right). Relatively higher activity levels of common pipistrelles compared with soprano pipistrelles can be observed in most squares except in the north west. Squares have no pie charts if no data is available.

Leisler's bat, *Nyctalus leisleri*, in 2004

Overall mean number of *Nyctalus leisleri* encounters per km for the July 2004 survey (Survey 1) is 2.8. The August (Survey 2) average is 4.2 encounters per km. The difference in encounter rates between the two months is not significant (95%) when a Wilcoxon signed rank test (non-parametric) is carried out on the data (for the squares where surveys were repeated). The overall average for both months in 2004 is 3.6 passes per km, see Table 2 above.

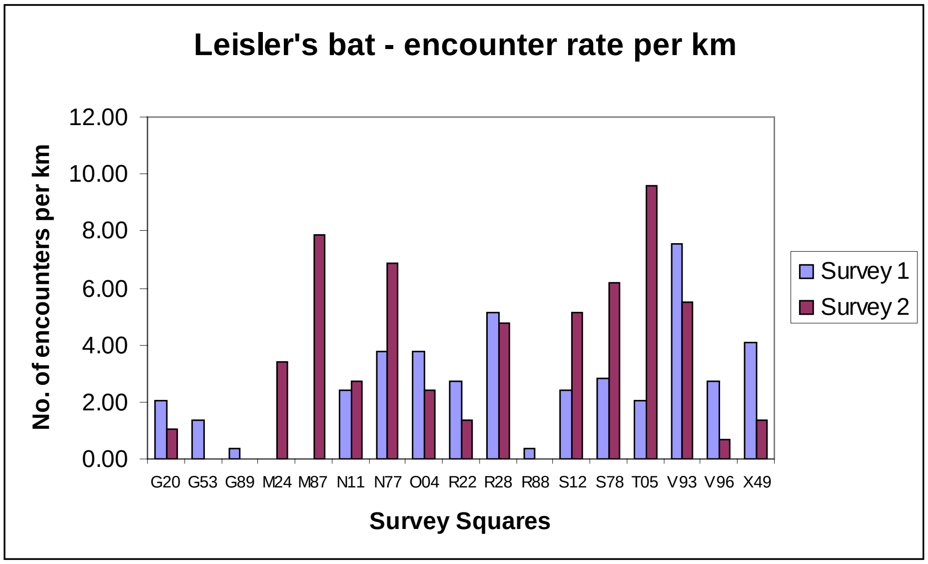


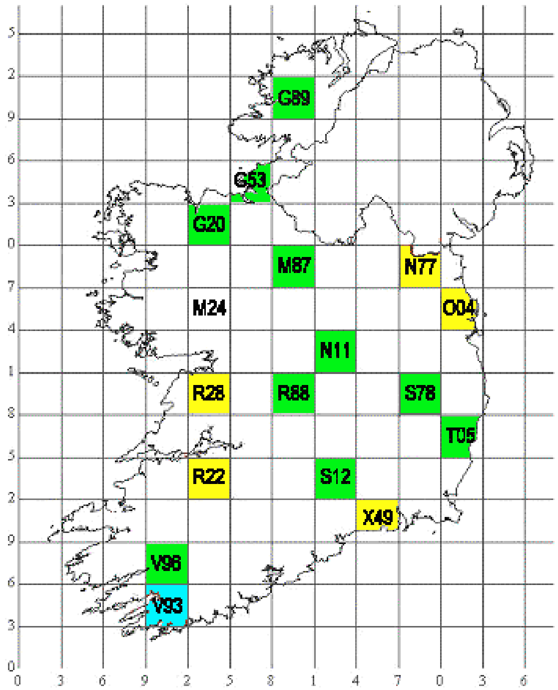
Figure 12: Average number of Leisler's bats, *Nyctalus leisleri*, encountered (i.e. picked up on the detector and recorded to the minidisc) per kilometre during July (S1) and August (S2) in 2004.

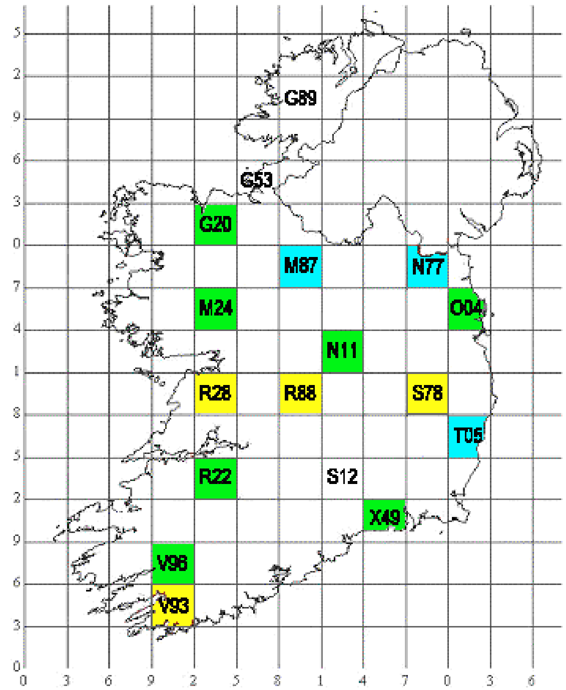
Particularly high Leisler's bat encounter rates were observed in T05 (S2) and M87 (S2). Low encounter rates were recorded from R88 (S1), G89 (S1) and V96 (S2).

Figure 13 provides an indication of particularly high encounter rate survey squares and relative changes in encounter rates between July and August for Leisler's bats. In addition, this mapping exercise can also be considered a cursory examination of relative countrywide activity distribution for the species.

No particular patterns of activity distribution of Leisler's bats can be derived from Figure 13 (above). However, some squares situated by the sea showed reductions in activity levels in August (compared with July), while some land-locked squares showed an increase from July to August. Overall increased levels of Leisler's bat activity from July to August are illustrated by a higher number of yellow and blue squares for that month.

Figure 13 (next page): Survey blocks colour coded according to Leisler's bat encounter rates. Map on left represents data from July 2004 and map on right represents data from August 2004. Green indicates the number of Leisler's encounters was below 3/km. Yellow indicates that the number of Leisler's encounters was greater than 3/km but lower than 6/km. Blue indicates that the number of Leisler's encounters was over 6/km. The overall average Leisler's encounter rate for 2004 was 3.5/km. Squares are not highlighted if no data is available.





Comparing 2003 and 2004 - *Nyctalus leisleri*
Figure 14 illustrates the difference between 2003 and 2004, in average number of Leisler's bat encounters per km for survey squares.

Higher numbers of Leisler's bats were encountered during surveys in most squares in August 2004 compared with August 2003 (R22 excepted). Results of a Wilcoxon signed ranks paired test (non-parametric) showed a significant difference ($z=2.197$, $p=0.03$) in overall Leisler's bat encounter rate in 2003 and 2004 (comparison was made between the same squares in both years).

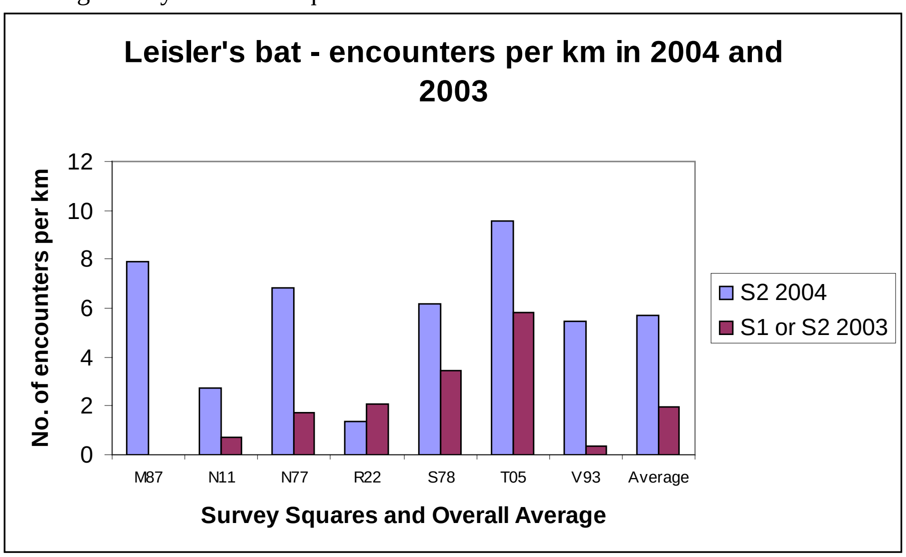


Figure 14: A comparison of average number of Leisler's bat, *Nyctalus leisleri,* encounters per km between those squares surveyed in 2003 and S2 (August) 2004. For 2003, S1 or S2 refers to the survey date most closely matching that of S2 of 2004 – see Table 3 for details. Average shown for 2003 (1.98 encounters per km) is derived from all survey squares, the average shown for 2004 (5.72 encounters per km) is derived solely from the seven survey squares that are included in the graph – to allow a direct comparison between years.

Myotis bats in 2004

Overall mean number of *Myotis* encounters per km for the July 2004 survey (S1) is 0.18. The August (S2) average is 0.53 encounters per km. The overall average for both months in 2004 is 0.34 passes per km, see Table 2 above.

Myotis bats were recorded from 11 of the 16 squares surveyed in 2004. The total number of *Myotis* encounters per transect did not exceed 2 in any square (not corrected to encounters per km sampled). The average number of *Myotis* bat encounters per km for the two survey months is not plotted because of the low number of occurrences.

Lesser horseshoe bat, *Rhinolophus hipposideros*, in 2004

One lesser horseshoe bat was observed in flight during a monitoring transect in square R28 in July. This bat was not picked up on the Duet bat detector. Two lesser horseshoe bats were heard in between monitoring transects in square V96 in July. No lesser horseshoe bats were observed or recorded during Survey 2 in August. No confirmed lesser horseshoe bat calls were recorded to minidisc from time expansion detectors.

The total number of encounters of this species is too low to warrant any statistical analysis.

August temperature compared with July temperature

Temperatures recorded by surveyors in July (prior to the start of monitoring) were significantly lower than temperatures recorded by surveyors in August. The result of a non-parametric Mann Whitney U test comparing recorded temperatures did indicate a significant difference ($p=0.02$). The mean temperature recorded in July was 14.5˚C (Standard Error: ±0.82), compared with a mean of 16.3˚C in August (Standard Error: ±0.63).

Streetlights

In 2004, surveyors were asked to record the number and colour of street lights occurring along monitoring transects. The presence of lights may impact bat activity levels since aerial insects are often attracted to street lights (depending on the colour). The total number of streetlights was recorded by many surveyors but difficulties arose with counting the many lights in villages and towns, while carrying out minidisc recording. In addition, differentiation between bright orange and pale orange or yellow lights was not sufficiently explained during training to allow surveyors to distinguish between types. As a result, a full dataset it not available for analysis for 2004. Further recommendations will be made for 2005.

Survey timing 2004

Revised methodology in 2004 compared with 2003 resulted in a later start in 2004. Surveyors waited until 45 minutes after sundown to begin monitoring compared with 30 minutes after sunset in 2003. The following Figure 15 indicates average numbers of bat encounters per km for each transect (1-20 where 1 is the first monitoring transect surveyed and 20 is the last monitoring transect surveyed).

For common and soprano pipistrelles the initial two transects have relatively low encounter rates. The first transect had a relatively low encounter rate of Leisler's bats. However, Leisler's bat numbers increased from the second monitoring transect onwards while common and soprano pipistrelle numbers began to increase from the third and fourth transects, respectively. The earlier increase in Leisler's activity compared with pipistrelle activity probably reflects the earlier emergence time of Leisler's bats.

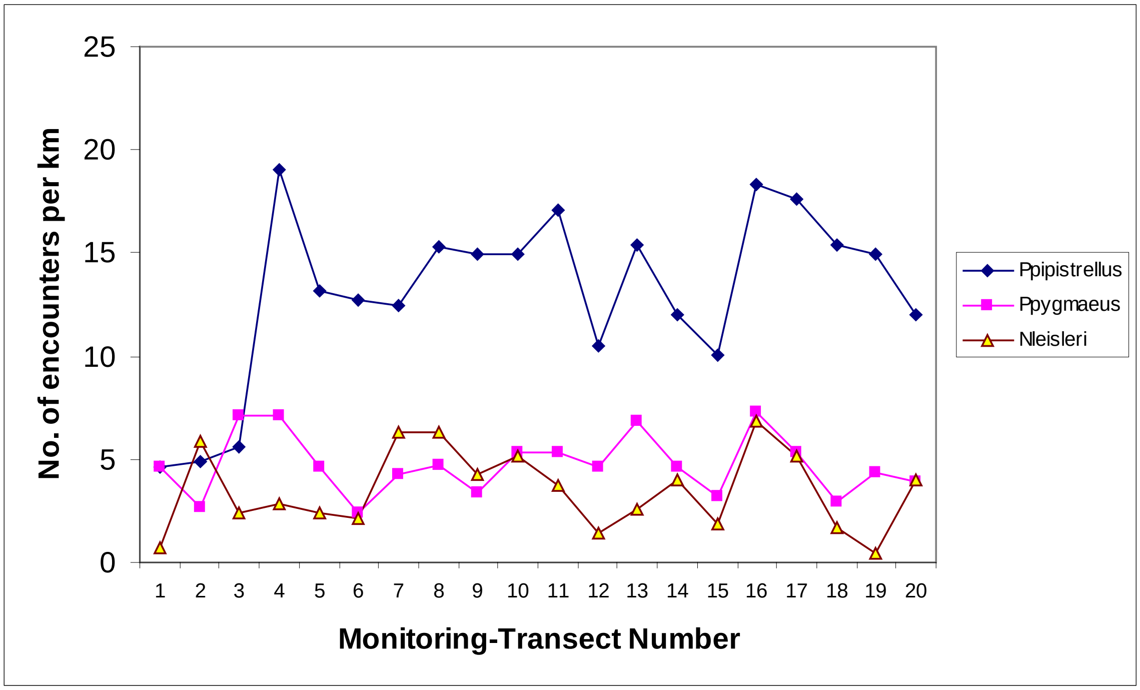


Figure 15: Variation in the mean number of encounters (per km) of common and soprano pipistrelles and Leisler's bats for each monitoring transect (N=27 to 29 depending on data available).

POWER ANALYSIS – DETECTING AMBER AND RED ALERTS

The exact methodology that was followed to derive Power Statistics for different bat species is given in Appendix I. Data from both 2003 and 2004 were used. All simulations are based on one-tailed tests for a decline at P=0.05 (equivalent to P=0.1 for a two sided test). As with all power analyses, results should be treated with caution as they are dependent on a lot of assumptions which will only be approximately correct. The results should be viewed as giving a rough indication of the usefulness of different designs for different species, rather than providing a definitive answer. The following tables summarise the results:

Table 4: Number of years surveying required to achieve 90% power for each species under the Amber (25% decline in 25 years) and Red (50% decline over 25 years) Alerts using two repeat surveys of each square per year (each square with 20, 1.609km, monitoring transects).

	Common pipistrelles		**Soprano pipistrelles**		**Leislers**	
Squares	**Amber**	**Red**	**Amber**	**Red**	**Amber**	**Red**
10	>25	11	>25	11	>25	14
15	20	10	>25	10	>25	11
20	17	10	23	10	25	10
25	15	9	18	9	22	10

Red Alerts can be determined by year 11 of surveying for common and soprano pipistrelles if 10 survey squares are surveyed twice annually. It would take slightly longer (14 years) to determine whether Leislers bats are in a Red Alert population decline. Amber Alerts will be difficult to establish (within 15 years) for most species unless a very high number of squares are surveyed twice every year.

Table 5: Number of years surveying with different numbers of transects or repeat surveys required to achieve 90% power for each species under the Red (50% decline over 25 years) Alerts. The left hand column for each species shows the same figures as the table above for comparison, whilst the other three columns show the effect of using 15 or 10 monitoring transects per square, or only doing a single survey.

	Common pipistrelles				**Soprano pipistrelles**				**Leislers**			
Transects	**20**	**15**	**10**	**20**	**20**	**15**	**10**	**20**	**20**	**15**	**10**	**20**
Surveys	**2**	**2**	**2**	**1**	**2**	**2**	**2**	**1**	**2**	**2**	**2**	**1**
Squares												
10	11	13	15	14	11	14	16	16	14	15	18	16
15	10	11	13	13	10	10	13	13	11	12	14	13
20	10	10	11	11	10	10	11	11	10	10	12	11
25	9	9	9	11	9	9	10	11	10	10	11	11

Reducing the number of transects per square or just doing a single survey per year both lead to some loss of power when the number of squares surveyed is small, but this reduction is less severe with larger numbers of squares.

OTHER WILDLIFE

Table 6: Total wildlife – other than bats – encountered during each survey, 2004. Values in brackets indicate dead individuals. + Value indicates that more than one individual was present but exact number was not specified by the recorder.

Square	Badger	Deer - Sika	Fox	Frog	Hare	Golden Plover	Hedge-hog	Mouse Field /House	Owl - Barn	Owl - Long-eared	Owl - Unid	Pine Marten	Pygmy Shrew	Rabbit	Rat
G20 1						1	2								
G20 2															
G89 1	1		1	1											
M24 2															
M87 1															
M87 2															
N11 1					(1)			2		1		1		1	
N11 2								1							
N77 1							1				1				
N77 2					1										
O04 1			1		1			1	1					7	1
O04 2			1		1		1								
R22 1			1 (1)				2				1			1	
R22 2											+1				
R28 1			1												
R28 2			1												
R88 1	1 (1)		2					1	1						
R88 2	1											1			
S12 1			1					2							(1)
S78 1															(1)
S78 2														2	
T05 1			1 (1)											1 (1)	
T05 2			(1)				(1)							1	
V93 1															
V93 2													1		
V96 1		5													
V96 2									1					2	
X49 1															
X49 2															
TOTAL	**3(1)**	**5**	**10 (3)**	**1**	**3 (1)**	**1**	**6 (1)**	**7**	**3**	**1**	**+3**	**2**	**1**	**15(1)**	**1(2)**

DISCUSSION

July and August bat activity levels

A number of factors may combine to result in slightly higher average bat encounters in August. Higher bat activity can be expected in higher temperatures since aerial insect numbers are positively correlated with temperature. Temperatures recorded in August were significantly higher than those recorded in July. In addition to raised temperatures, young bats born in June may be on the wing by mid-August, thus causing an overall increase in bat abundance for that month compared with other summer months.

Overall bat activity 2003 - 2004

Consistently higher mean numbers of bat encounters per kilometre were observed in 2004 (common and soprano pipistrelles and Leisler's bats). This may be partly due to a lower sample size available for analysis from 2003. There are, however, two other reasons why higher bat activity could be expected in 2004:

- The slightly later survey start time of 45 minutes after sunset in 2004 (compared with 30 minutes after sunset in 2003) meant that bats were often detected from the start of the first transect.
- Secondly, most second survey squares (S2) were completed by mid-August in 2004, compared with late August in 2003.

As a result of the slight changes in methodology and the much higher number of squares covered in 2004 compared with 2003 – population trends cannot yet be deduced.

Power

Results of Power analysis show that the present survey method is robust enough to highlight red alert declines in Leisler's bat and in common and soprano pipistrelle populations within approximately 10-15 years (or less) of monitoring. In 2004, full datasets from 10 repeated squares were available, along with partial data, or data from one survey only, from an additional 7 squares.

A number of strategies have been investigated to determine:

- the minimum number of squares
- the minimum number of repeats and
- the minimum number of transects

that need to be surveyed every year to achieve power.

Results show that any reduction in the number of squares or transects covered tends to lead to a loss in Power (for predicting Red Alerts).

Allowing for surveyor availability, weather and occasional equipment problems it cannot be assumed that each of the 17 currently mapped squares will be covered twice in full each year. 10 were achieved in 2004 but a potentially higher number could be covered in 2005 once equipment difficulties have been resolved. It is important to have as large a number of squares covered as possible because this ensures there is good coverage of the entire country and future habitat studies will benefit from country-wide coverage. Should volunteers favour a slight reduction in the number of transects covered from 20 to 15 this would lead to a marginal, but not excessive loss in power. This possibility can be discussed with surveyors prior to the start of 2005 surveying.

Other Wildlife

Fourteen additional species were recorded by surveyors during the 2004 bat monitoring scheme (see Table 6). Rabbit was the most commonly recorded additional species and was noted on 15 occasions. Foxes were also regularly seen, although more than one live specimen was never noted on a single monitoring transect. Hedgehogs and mice were also relatively frequent. Interesting records include two pine marten and a number of owls (long-eared and barn owls).

RECOMMENDATIONS FOR 2005

1. Surveying for 2005 should take place at the same time of year as in 2004.

2. Devise an additional training minidisc for surveyors so that they are fully aware of potential problems and how to remedy them quickly.

3. Purchase three high quality leads for each survey square so that problematic leads can be immediately replaced in the field.

4. Calibrate each tranquility transect bat detector so that results can be corrected for differences in sensitivity of the detectors.

5. Highlight 10 core squares which must be covered twice every year and ensure that replacement surveyors are available to carry out the work in those squares, if necessary.

6. Ensure quality training is given to any new surveyors for 2005.

7. Additional squares should also be surveyed but may not have to be surveyed twice annually.

8. Discuss with surveyors what strategy they would like to see employed – continue as at present or reduce transect number from 20 to 15 (cutting out the last 1 hour of survey work).

9. Power Statistics has been carried out for the two year's data and results show that the method is sufficiently sensitive to detect Red Alert declines in certain bat populations. 2005 analysis can focus on activity levels, distribution, weather and, if funds are available, preliminary investigation into habitat usage research could be carried out.

10. Consider the best method for recording streetlights in the field.

11. Consider and suggest strategies for future monitoring of other bat species:
    - *Myotis daubentonii*
    - *M. mystacinus*
    - *M. nattereri*
    - *M. brandtii*.
    - *Plecotus auritus*

12. Ensure that all datasets (raw data and analysed data) is stored safely by Bat Conservation Ireland.

13. To ensure continuity of quality of sonogram analysis BCT should carry out quality control each year on a random sample of the dataset.

14. Ensure each surveyor is provided with a copy of the annual report and invite feedback on the survey programme.

15. Volunteers expenses should continue to be covered from the survey costs.

16. The addition of a third (substitute) surveyor for each square may be beneficial and should be pursued.

17. Further investigations must be carried out to determine more fully the effects of driving speed so that any bias introduced to the survey data by relatively high or low speeds can be factored into future analyses.

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ACKNOWLEDGEMENTS

We would like to thank each of the 37 people who devoted long and antisocial hours to map and survey routes throughout the country.

Tina Aughney
Stephen Aughney
John Biggane
Sinéad Biggane
Shaun Boyle
Daniel Buckley
Carl Byrne
Susan Callaghan
Joe Costelloe
Miriam Crowley
Emma Glanville
Rebecca Jeffrey
Brian Keeley
Conor Kelleher
James Kilroy
Deirdre Lynn
Liam Lysaght
Seppie Lysaght
Kate McAney
Dave McDonagh
Emer McGee
Barbara McInerney
James Moran
Enda Mullen
David Norriss
Áine O'Connor
Séamus O'Connor
Ciarán O'Keeffe
Ciara O'Mahony
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Thanks also to NPWS (Ferdia Marnell, Deirdre Lynn and Rónán Whelan) and The Heritage Council (Liam Lysaght) for their help co-ordinating the project.

GLOSSARY/DEFINITIONS/ABBREVIATIONS

Survey square – a randomly generated 30km² square within Republic of Ireland

Survey route – a 93.3 km (58 mile) driven route within a survey square

Monitoring transect – a 1.609 km (1 mile) transect spaced every third of 1.609 km (mile) along a survey route.

BAT SPECIES PRESENT IN IRELAND

Common Name	***Scientific Name***
Daubenton's bat	*Myotis daubentonii*
Whiskered bat	*Myotis mystacinus*
Natterer's bat	*Myotis nattereri*
Brandt's bat	*Myotis brandtii*[2]
Leisler's bat	*Nyctalus leiseri*
Nathusius' pipistrelle	*Pipistrellus nathusii*
Common pipistrelle	*Pipistrellus pipistrellus*
Soprano pipistrelle	*Pipistrellus pygmaeus*
Brown long-eared	*Plecotus auritus*
Lesser horseshoe bat	*Rhinolophus hipposideros*

NOTE

Although 'miles' are used in the protocol (car odometers are in miles) we have standardised in kilometres throughout this report

(1 mile = 1.609 km)

[2] This species has been recorded by two bat workers at three locations in Ireland to-date (E.Mullen and B.Keeley *pers.comm.*), but has yet to be confirmed as a resident species.

APPENDIX I

Methods

In 2003 the general approach was:

- Surveyors were identified and provided with appropriate training.
- Each surveyor was allocated a randomly selected $30km^2$ square.
- Each surveyor devised a route with 20 - 1 mile transects within the square.
- Results were analysed with respect to monitoring sensitivity.
- Recommendations were made to improve the methodology in 2004 and with regard to long-term monitoring.

This protocol was again followed in 2004. Additional surveyors from National Parks and Wildlife Service staff volunteered to take part in the programme.

Volunteers were presented with an information pack which included an outline of the protocol for the car survey, a distribution map showing twenty randomly generated $30km^2$ survey blocks, a map showing part of an overall route with examples of monitoring transects, a list of sunset times for areas within the Republic of Ireland, guidelines for using a minidisk recorder, and two recording sheets, one to record transect details and one to record survey information. In addition, each volunteer was equipped with maps, a minidisk recorder, a stereo connecting lead, a bat detector (Tranquility Transect), a car window mounting clamp, a thermometer, a first aid kit and a flashing beacon.

A car transect method was employed to monitor bat activity within twenty 1.609 km (1 mile) monitoring transects along a selected survey route within randomly generated $30km^2$ squares. Time expansion bat detectors were employed to assess bat activity along the route and bat calls were recorded onto a minidisc recorder.

A training day to explain the project to new volunteers and demonstrate the equipment was carried out in June 2004.

Each volunteer was assigned at least one 30 km^2 survey square and asked to choose a suitable survey route within each block comprising of twenty 1.609 km (1 mile) monitoring transects spaced 3.218 km (two miles) apart. Details of the transect route were recorded by the surveyor on the appropriate form and highlighted on the maps provided.

Each survey square was driven in July 2004. A repeat survey was carried out in August 2004. The bat detector was positioned at 45° to the rear of the car in the horizontal plane and 45° to the vertical plane as previous work had shown that this angle minimised background noise and interference. Surveying began 45 minutes after sunset and volunteers were required to drive at 24kmph along each monitoring transect, recording bat activity via the bat detector onto the minidisk recorder. This low speed was chosen because low speeds reduce background noise and the effect of Doppler shifts on recorded calls (for details see Catto *et al.* 2004).

Sonographic analysis

Time expansion audio data was transferred to the computer hard drive as separate *.wav files representing the numbered tracks (20 files, one for each monitoring transect) on the minidisk using the software Win Nmd (v1.2x, Christian Klukas). Occasionally, multiple tracks were recorded for each monitoring transect and these were joined into a single *.wav file using the software program AddAWav (v1.5, Geoff Phillips). Using Bat Sound (Pettersson Elektronik AB) software, bats were categorised into species from the measured parameters of their echolocation calls.

Each adjacent 320ms time expanded sequence was treated as an independent sample, and therefore species occupying adjacent 320ms sequences were treated as separate individuals. It was occasionally possible to identify more than one individual of the same species within a single 320 ms sequence. The maximum number of species identified in any one 320ms sequence was four.

Power analysis method

Power statistical analysis was carried out on data obtained from 2003 and 2004 to determine whether this monitoring technique is sensitive enough to pick up Red Alerts in bat populations.

All simulated population trend declines are based on one-tailed tests for a decline at $P = 0.05$ (equivalent to $P = 0.1$ for a two sided test). Results should be treated with caution as they are dependent on many assumptions, some of which will only be approximately correct. In particular, the data for soprano pipistrelles and Leisler's bat contain a high proportion of zeros and the results are sensitive to the precise way in which the data is simulated.

Power analysis was used to answer 2 fundamental questions:

1) After 25 years monitoring how many monitoring transects are required to achieve 90% Power, giving a 90% chance of detecting a significant decline, when the true decline is a) 1.14% per year (Amber Alert) or b) 2.73% per year (Red Alert)?
2) For different numbers of monitoring transects surveyed annually, how many years monitoring is required to achieve 90% Power, giving a 90% chance of detecting a significant decline, when the decline occurring is a) 1.14% per year (Amber Alert) or b) 2.73% per year (Red Alert) for each species?

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. The steps involved are:

1. Fit a REML model to the log-transformed ($\log10(x+1)$) counts per minute of recording time in order to estimate the components of variance.

2. Simulate lognormal data with variances equal to the estimated ones, and the same mean and proportion of zeros as the real data. These are then converted to counts in 75 0.32second recording periods for fitting the GAM model.
3. See how often significant declines are detected (judged by means of the 90% bootstrap confidence limits from a GAM model) in a large number of simulated data sets, after adding year effects to represent the desired declines.
4. Polynomial models are fitted to the results from 3 to smooth them and to allow extrapolation to scenarios not directly simulated.

The REML models were fitted using the average number of passes per minute for each 1 mile long monitoring transect[3]. The small number of instances where the monitoring transect contained less than 50 0.32 second recording periods are excluded, as the models suggested that these produced abnormally low counts. No attempt was made to fit models to the *Myotis* spp. data (or to the indeterminate pipistrelles) as there was far too little data to permit sensible modelling.

[3] Encounters per minute are directly correlated with encounters per km – see Figure 4 main report.

APPENDIX II

Results

Table A1: Time spent by Volunteer Surveyors

Activity	Time (minutes)
Time spent per survey route	
Route preparation	Approx 210 (3 hours 30mins)
Carrying out first survey route	237 (N=15) (3 hours 57 minutes)
Carrying out repeat route	230 (N=11) (3 hours and 50 minutes)
Total survey time in 2004	
Route preparation	1890 (N=9) (31 hours 30 minutes)
Carrying out first survey route	3792 (N=16) (63 hours 12 minutes)
Carrying out repeat survey route	3450 (N=15) (57 hours 30 minutes)
TOTAL TIME SPENT 2004	**9132 (152 hours 12 minutes)***

*Note that this does not include surveyor partners' time.

Table A2: List of survey squares with survey dates (2004). The code for each survey square indicates the south-west grid-reference of the 30km² block based on the Irish Grid system.

Survey Route	Date of Survey 1	Date of Survey 2
G20	20/07/04	17/08/04
G53	21/07/04	10/08/04
G89	15/07/04	-
M24	-	13/08/04
M87	23/07/04	12/08/04
N11	21/07/04	12/08/04
N77	17/07/04	14/08/04
O04	21/07/04	09/08/04
R22	25/07/04	14/08/04
R28	23/07/04	10/08/04
R88	23/07/04	17/08/04
S12	17/07/04	-
S78	19/07/04	28/07/04
T05	17/07/04	13/08/04
V93	23/07/04	13/08/04
V96	16/07/04	03/08/04
X49	20/07/04	20/08/04

Table A3. Mean time taken to complete 1.609 km (1 mile) monitoring transect. SD = standard deviation. All values are in seconds. Note that 240 seconds is equivalent to a driving speed of 15 miles or 24km per hour.

Survey Block & Date	Mean	SD	Minimum	Maximum
G20 20-07-04	313	28	271	380
G20 17-08-04	305	30	260	370
G53 21-07-04	254	13	236	296
G89 15-07-04	314	38	271	405
M24 13-08-04	336	31	303	433
M87 23-07-04	256	15	232	271
M87 12-08-04	259	10	236	275
N11 21-07-04	264	17	229	292
N11 12-08-04	271	27	232	320
N77 17-07-04	268	19	208	303
N77 14-08-04	260	28	218	303
O04 21-07-04	252	11	232	271
O04 09-08-04	251	13	225	285
R22 25-07-04	281	19	250	334
R22 14-08-04	307	53	232	465
R28 23-07-04	272	19	239	320
R28 10-08-04	272	19	232	303
R88 23-07-04	254	14	232	282
R88 17-08-04	254	13	232	285
S12 17-07-04	252	7	239	260
S78 19-07-04	249	16	225	278
S78 28-07-04	240	12	215	257
T05 17-07-04	243	10	229	268
T05 13-08-04	276	13	250	296
V93 23-07-04	268	16	250	310
V93 13-08-04	275	13	246	296
V96 16-07-04	272	18	236	317
V96 03-08-04	277	14	257	299
X49 20-07-04	285	28	239	356
X49 20-08-04	278	27	236	348
OVERALL	**273**	**32**	**208**	**465**

REML RESULTS

REML (Restricted or Residual Maximum Likelihood) models allow the estimation of multiple variance components. In the context of population surveys, they permit the estimation of the variance due to factors such as sites, years and surveys. REML models assume normality and so data must first be transformed (e.g. by logs) to achieve approximate normality. In the context of power analysis, the variance estimates can then be used to simulate artificial data with known trends which resembles real population data.

The variance components from the REML analysis are shown below:

Table A4: Variance components estimated from the REML model of passes per minute.

Component	Explanation	Pip 45	Pip 55	Leislers
square	Variation between 30 km squares	0.0267	0.0073	0.0000
square.transect	Variation between monitoring transects within squares	0.0233	0.0136	0.0062
square.year	Variation between years within squares	0.0000	0.0004	0.0014
square.transect.year	Variation between years within monitoring transects	0.0064	0.0000	0.0009
square.minitrans.year.rep	Variation between reps within transects and years	0.1651	0.1030	0.0930

It is possible to break the variation down into more components now that two years of data are available, although the precision of some of the estimates (especially square.year) will still be very poor. Remembering that it is the relative magnitude of the different components for a species that is of interest, the most obvious feature of these estimates is that by far the largest source of variation for all species is the residual variation between replicate surveys of the same 1 mile transect in the same year. The square.transect variation is always reasonably large, indicating that some transects are consistently better in terms of bat passes than others. For the common pipistrelles in particular, there was also consistency between survey routes, as indicated by the ‘square’ component.

These results are not particularly surprising, and the main interest in these components is purely as a device to generate realistic simulated data for predicting the power of different survey designs.

It is worth noting that the REML models showed some significant differences between the results from the two years, with 2004 being higher for all three species. This is shown in the tables below; since the distributional assumptions of the REML analyses are rather dubious due to the high numbers of zeros, instead, the difference has been tested using a non-parametric Wilcoxon test on those squares with data from both years.

Table A5: Mean encounters tabulated by year, together with estimated means and standard errors on the log scale from the REML model.

a) Common pipistrelles

Year	**Mean encounters per minute**	**Estimated mean on log-scale**	**Standard error**
2003	3.00	0.29	0.056
2004	4.80	0.47	0.044
Wilcoxon test P = 0.016			

b) Soprano pipistrelles

Year	**Mean encounters per minute**	**Estimated mean on log-scale**	**Standard error**
2003	1.15	0.16	0.037
2004	1.71	0.25	0.026
Wilcoxon test P = 0.031			

c) Leisler's

Year	**Mean encounters per minute**	**Estimated mean on log-scale**	**Standard error**
2003	0.72	0.11	0.027
2004	1.30	0.17	0.014
Wilcoxon test P = 0.047			

All three species show significant increases (possible reasons are discussed in main report).

POWER ANALYSIS RESULTS

The GAM (Generalized Additive Models) models are based on the method described in Fewster *et al.* (2000). These involve fitting a log-linear generalised model (i.e. a regression model with a logarithmic relationship to the explanatory variables and Poisson error distribution) to the counts on each survey. A site term is fitted in the model to allow for differences in abundance between sites and the time trend is modelled using the GAM framework to fit a smoothed curve. The time trend is then expressed as an index, with the value of 100 representing the population size in the base year (generally the first year of the survey). The confidence limits for the GAM trend are obtained by a bootstrapping process in which a large number of artificial datasets are generated by sampling sites at random from the dataset. The confidence limits are also used as the basis for significance tests; if the confidence limits in a particular year do not include the value of 100, the trend is considered significant.

The GAM approach is so computationally intensive that only a limited number of combinations of numbers of squares and numbers of years with limited replication have been evaluated so the tables presented in the main report are reliant on the polynomial regression models to allow estimation for all scenarios.

The power over a 25 year period are shown graphically in Figures A1 – A3. A second set of graphs shows the results for a 10 year period Figures A4-A6.

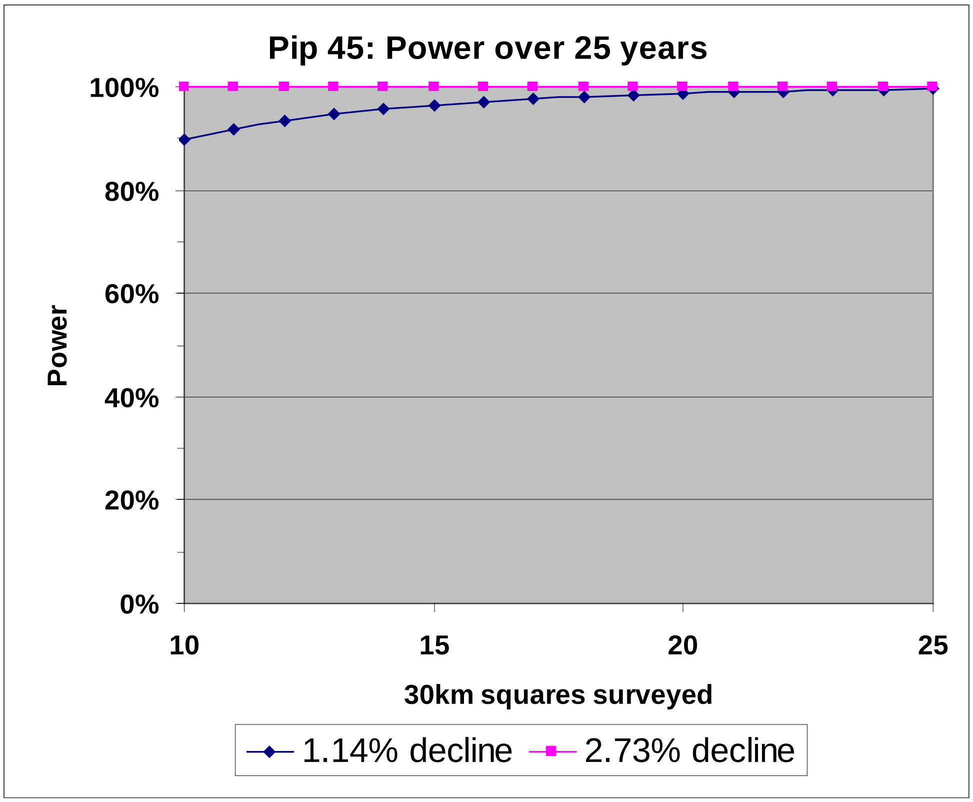

Figure A1: Power over 25 years for common pipistrelles (*Pipistrellus pipistrellus*).

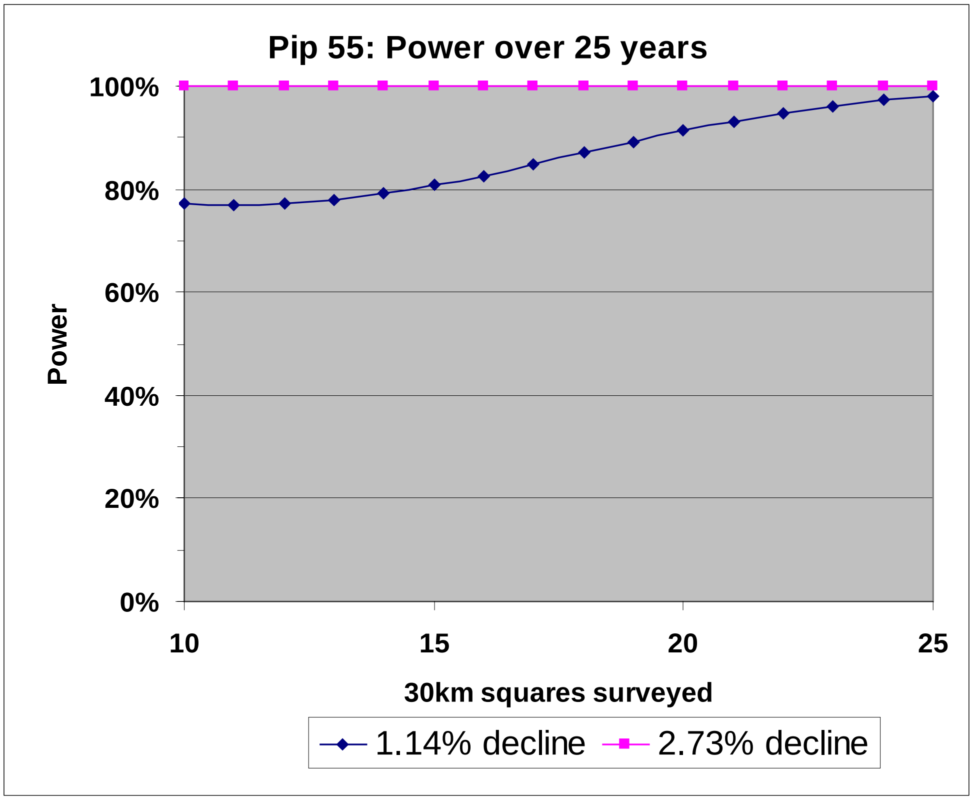

Figure A2: Power over 25 years for soprano pipistrelles (*Pipistrellus pygmaeus*).

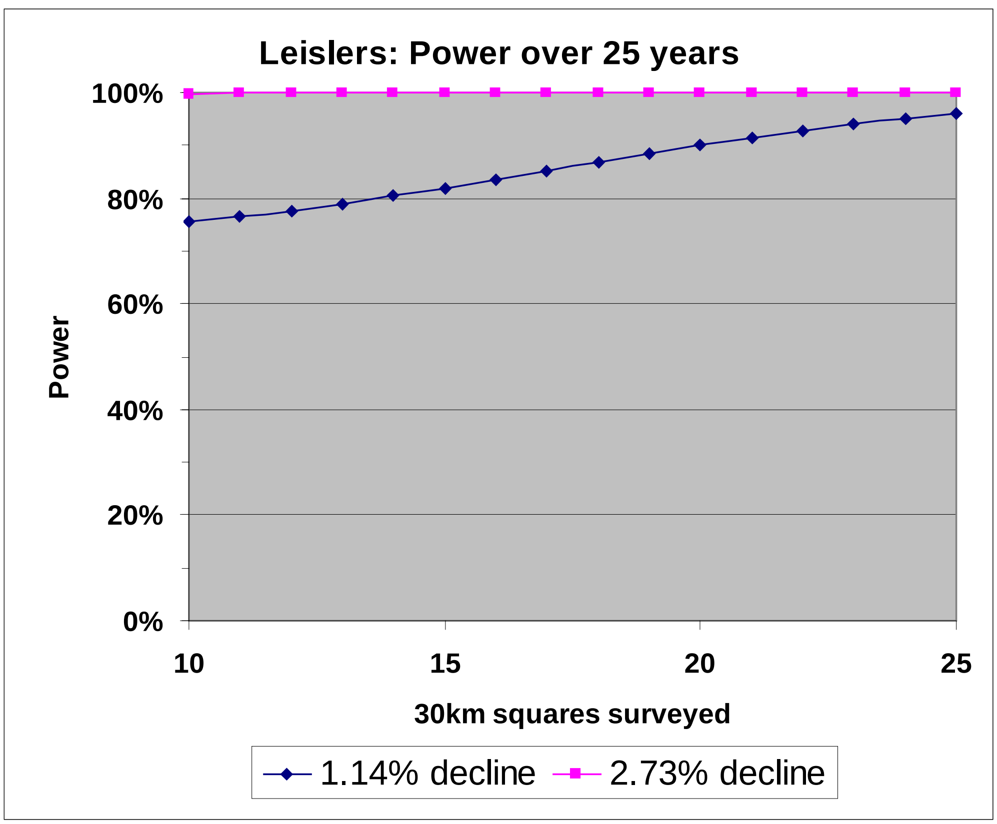

Figure A3: Power over 25 years for Leisler's bats (*Nyctalus leisleri*).

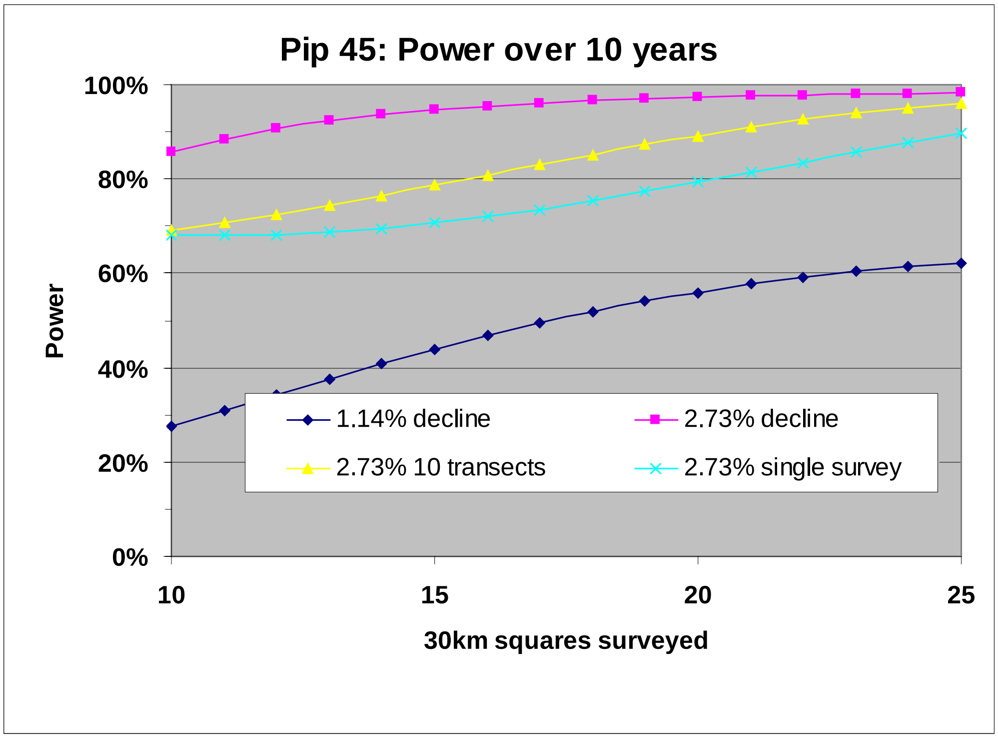

Figure A4: Power over 10 years for common pipistrelles (*Pipistrellus pipistrellus*).

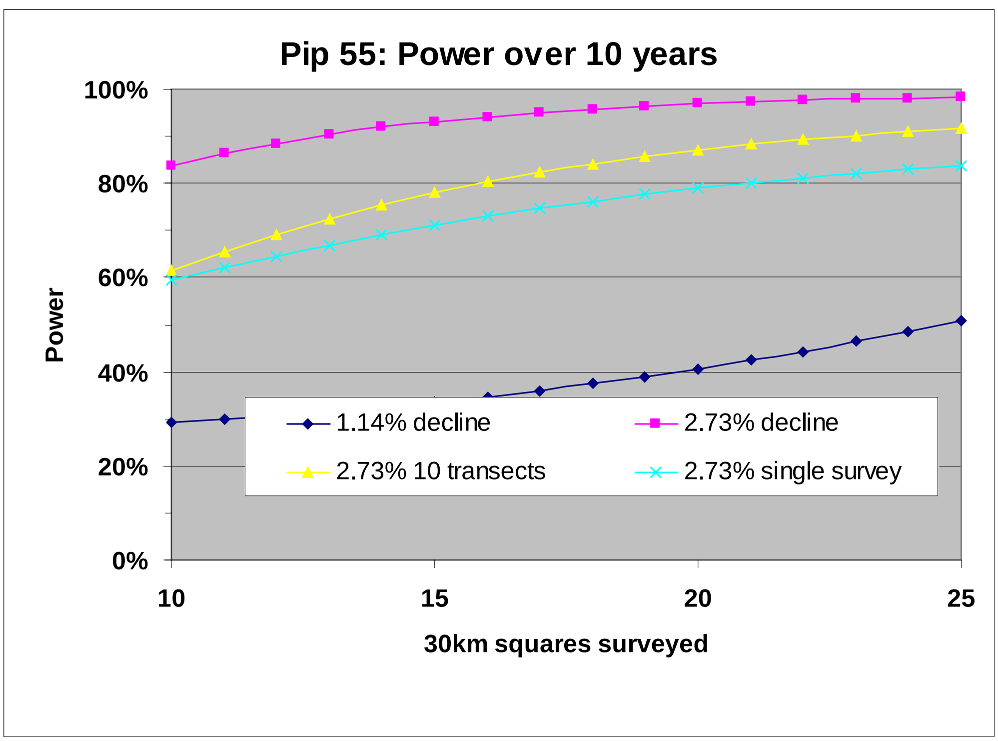

Figure A5: Power over 10 years for soprano pipistrelles (*Pipistrellus pygmaeus*).

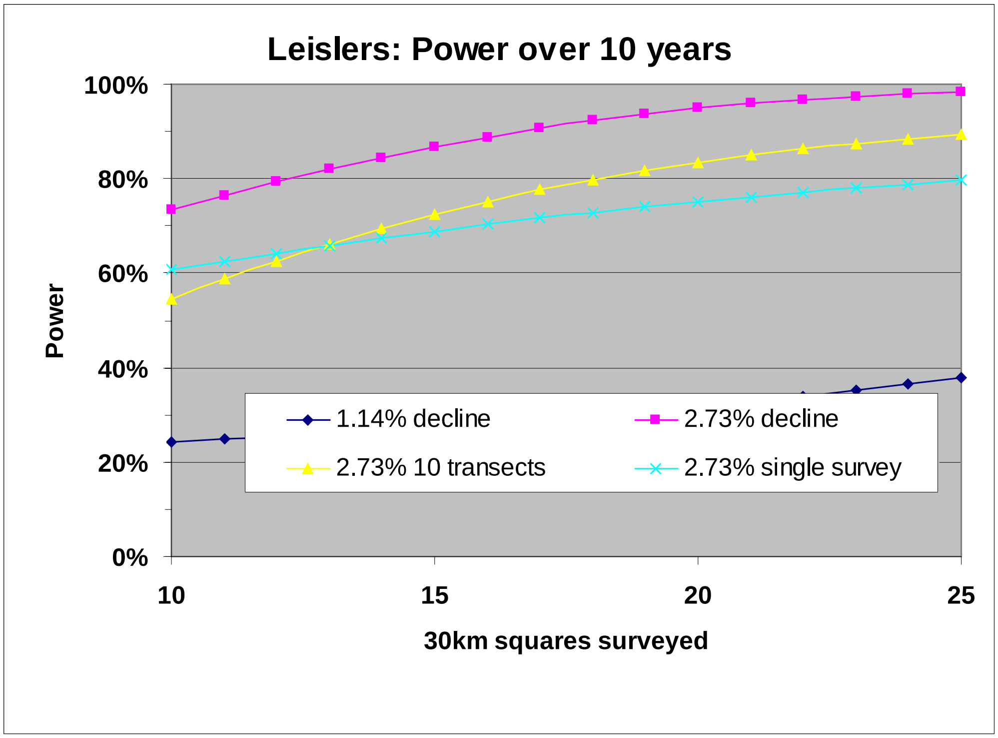

Figure A6: Power over 10 years for Leisler's bats (*Nyctalus leisleri*).

REFERENCE

Frewster, R.M., Buckland, S.T., Siriwardena, G.M., Baillie, S.R. and Wilson, J.D. (2000). Analysis of population trends for farmland birds using generalized additive models. *Ecology* **81**: 1970-1984.