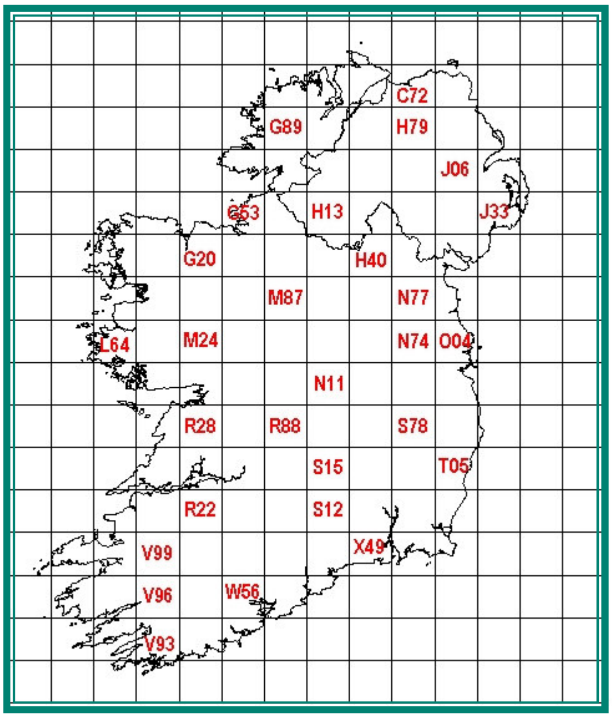
The Car-Based Bat Monitoring Scheme for Ireland: Synthesis Report 2003-2008



Irish Wildlife Manuals No. 39

Comhshaol, Oidhreacht agus Rialtas Áitiúil
Environment, Heritage and Local Government

The Car-Based Bat Monitoring Scheme for Ireland:
Synthesis Report 2003-2008

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

1. www.batconservationireland.org

2. stats@slangton.co.uk

Citation:

Roche N., Langton S. and Aughney T. (2009) The Car-Based Bat Monitoring Scheme for Ireland: Synthesis Report 2003-2008. *Irish Wildlife Manual*s, No. 39. National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Dublin, Ireland.

Cover image: Map of Ireland showing car transect survey squares

Irish Wildlife Manuals Series Editors: F. Marnell & N. Kingston

ISSN 1393 – 6670

CONTENTS

EXECUTIVE SUMMARY

The first systematic car-based bat monitoring system in Europe was devised for the Republic of Ireland (ROI) in 2003 by the Bat Conservation Trust (BCT, UK) and funded by the Irish Heritage Council. The scheme has been administered by Bat Conservation Ireland (BCIreland) since 2004. The scheme has expanded year on year, funded by the National Parks and Wildlife Service (NPWS) of the Department of Environment, Heritage and Local Government (ROI). In 2006 it was extended to Northern Ireland with additional funding from the Northern Ireland Environment Agency (NIEA), formerly Environment and Heritage Service, Department of the Environment, Northern Ireland. The main aim of the scheme is to monitor roadside populations of common pipistrelle, soprano pipistrelle and Leisler's bat and to collect sufficient data to identify trends in bat populations.

The method involves driving a known survey route at 24kmph (15mph) with a time expansion bat detector clamped to the open window of the passenger door. Each survey route (route length is 93km) consists of 20, 1.6km transects, separated by a 3.2km gap to prevent repeat encounters with the same bats. Sounds are recorded to minidisc. Minidisc recordings are analysed by BCIreland using Bat Sound™ software. In the initial pilot study in 2003, routes were mapped and surveyed within seven, randomly selected, 30km squares. The coverage across the country increased yearly until 2007, when routes had been mapped in 28, 30km blocks. Surveys are carried out in July and August by trained volunteers who are mainly staff of NPWS and NIEA, and BCIreland members. Between 60 and 70 surveyors spend approximately 400hrs per annum carrying out the survey. While approximately 35% of volunteers (or 22 out of 60) do not survey the following year, the repetition rate for team leaders is very high, with just 17%, or 6 out of 25 failing to repeat the survey the following year.

Out of a possible total of 28 squares up to 27 have been surveyed on any given year. Between 998km and 1576km of monitoring transects have been driven each year since 2004. From 2003 to 2008, 6543km of monitoring transects have been surveyed. In total, 13606 bat encounters have been recorded by this monitoring scheme.

The common pipistrelle is the most frequently encountered species. On average 1.68 common pipistrelle encounters are recorded during each 1.6km monitoring transect. The soprano pipistrelle is usually the second most frequently encountered species each year. On average 0.67 soprano pipistrelle encounters are recorded from each 1.6km transect. The Leisler's bat is usually the third most frequently encountered bat species. On average, 0.66 Leisler's bats are encountered during each 1.6km transect. Other species such as Myotis *spp*., Nathusius' pipistrelle and brown long-eared bats are encountered by the survey in very low numbers.

An examination of average bat abundance and bat diversity in each square shows that the most abundant squares are found in the south west and east of the country, while the most diverse square tend to be those with low encounter rates, situated in the north and north west. A combination of the two factors, however, highlights a number of squares with relatively high diversity and high abundance. These squares are V93 (west Cork) and V96 (Killarney) in the south west, and S78 in Carlow/west Wicklow.

Simple linear models fitted to the yearly encounter rate data for each species show that common pipistrelles may be on an increasing trend. Trends for soprano pipistrelles are less clear but this species may also be on the increase. Leisler's bat, likewise appears to show an increasing trend. Nathusius' pipistrelle, which had been thought to be on the increase, now appears to be declining from its high level in 2006, although encounter rates with this species are so low that standard error bars are very wide. Likewise, error bars for *Myoti*s species' yearly estimates are too wide to determine trends.

Power analysis was carried out to determine whether Red and Amber Alert declines in the three target species can still be detected by the monitoring scheme. Results of this analysis confirm that when 20 squares are surveyed twice yearly a Red Alert decline can be detected within 8, 11, and 12 years for common pipistrelles, soprano pipistrelles and Leisler's bats, respectively. Amber Alerts take roughly twice as long to detect, although exact numbers vary between species. An examination of power of the data to detect increases shows that results roughly mirror the ability to detect declines, with a similar number of squares needed to detect either a doubling or halving of the population. For 20 squares surveyed twice annually it would take 9, 11 and 12 years to detect a 100% increase (over 25 years) in common pipistrelles, soprano pipistrelles and Leisler's bat, respectively.

With the issue of driver and surveyor safety of primary concern, investigations were carried out in 2008 to determine whether it will be feasible to reduce the time taken to complete an individual survey. Power analysis was carried out to determine the impact of reducing the number of transects surveyed each night. Results show that cutting out the last 5 transects has very little impact on the number of years required to detect Red or Amber alert declines in common pipistrelles or Leisler's bats, but does increase the time needed to pick up Alerts in soprano pipistrelles by 2-3 years. Cutting out the final 5 transects at the end of each survey would reduce average time to complete a survey to three hours, from the current average of four hours.

Other vertebrates were recorded by surveyors during each survey night and in total 1109 living vertebrates other than bats have been recorded from 13014km of roads in July and August 2006 to 2008. The most common species is the domestic cat, which accounts for 52% of all living vertebrates observed. Cat abundance has increased since 2006. The next most common species encountered are foxes and rabbits. By way of contrast the most commonly recorded dead vertebrates are rabbits, followed by badgers and foxes.

Acknowledgements

A very special THANK YOU to the surveyors from 2003 to present:

Stephen	Aughney	Rebecca	Jeffrey	Ciara	O'Mahony
Tina	Aughney	Brian	Keeley	Elaine	O'Riordáin
Eric	Bann	Conor	Kelleher	Cormac	Parle
Ted	Barker	Tara	Kelleher	Una	Patterson
Chris	Barron	Ger	Kelleher	Chris	Peppiatt
Imelda	Barry	Gerry	Kelly	Gill	Robb
Dominic	Berridge	Bee	Kesso	Niamh	Roche
John	Biggane	James	Kilroy	Gráinne	Roche
Eileen	Biggane	Naomi	Kingston	Tim	Roderick
Sinéad	Biggane	Annette	Lynch	Lorcan	Scott
Andy	Bleasdale	Deirdre	Lynn	Joe	Sheehan
Emma	Boston	David	Lyons	Lorna	Somerville
Patricia	Boston	Bella	Lysaght	Ger	Stanton
Shaun	Boyle	Liam	Lysaght	Robert	Steed
Daniel	Buckley	Pauli	Lysaght	Jonathan	Stevenson
Kieran	Buckley	Seppie	Lysaght	Yvonne	Temple
Carl	Byrne	Kevin	Maguire	Georgina	Thurgate
Susan	Callaghan	Mary	Maguire	Dave	Tierney
Ruth	Carden	Fidelma	Maher	Deirdre	Toomey
Stephen	Carters	Ferdia	Marnell	Kathryn	Turner
Donna	Cassidy	Kate	McAney	Fernando	Valverde
Damian	Clark	Eddie	McCourt	Alyn	Walsh
Jimi	Conroy	Annie	McCourt	Gemma	Weir
Joe	Costelloe	James	McCrory	Betty	White
Kerry	Crawford	Lee	McDaid	Chris	Wilson
Denis	Crinigan	Larry	McDaid	Jane	Woodlock
Sarah	Crinigan	Dave	McDonagh	Cathy	
Miriam	Crowley	David	McDonagh		
Reggie	Cunningham	Juliet	McDonnell		
Guy	Dalton	Emer	McGee		
Hannah	Denniston	Barbara	McInerney		
Paschal	Dower	Melina	McMullan		
Catherine	Farrell	Michael	McNamara		
Fiona	Farrell	Simon	Mickleburgh		
Mairead	Farrell	Robbie	Miller		
Aine	Fenner	Ken	Moore		
Andrew	Fenner	James	Moran		
Jennifer	Firth	Enda	Mullen		
Leonard	Floyd	Sinead	Noonan		
Bill	Forrest	David	Norriss		
Kathryn	Freeman	Irene	O'Brien		
Emma	Glanville	Mark	O'Callaghan		
Paddy	Graham	Áine	O'Connor		
Gareth	Grindle	Séamus	O'Connor		
Clare	Heardman	A.	O'Donaill		
Catherine	Higgins	Jim	O'Donoghue		
Therese	Higgins	Sylvia	O'Hehir		
Rob	Holloway	Dennis	O'Higgins		
Austin	Hopkirk	Ciarán	O'Keeffe		

Thanks also to

- Our funding partners, the Northern Ireland Environment Agency:

- Staff of NPWS, in particular Naomi Kingston, Deirdre Lynn and Ferdia Marnell.
- Staff of the Northern Ireland Environment Agency in particular Donna Cassidy and John Milburne.
- Jon Russ of the BCT.
- Liam Lysaght.
- Colin Catto.

INTRODUCTION

The Car-Based Bat Monitoring Scheme is a joint project of The National Parks and Wildlife Service (NPWS) of The Department of Environment, Heritage and Local Government, Republic of Ireland, The Northern Ireland Environment Agency (NIEA) of the Department of the Environment, Northern Ireland and Bat Conservation Ireland (BCIreland). This project aims to be the primary tool for monitoring roadside populations of common pipistrelle, soprano pipistrelle and Leisler's bats in Ireland. The project protocol was initially devised and piloted by The Bat Conservation Trust (BCT) in 2003 as an initiative of The Heritage Council (ROI) (Catto *et al*., 2004).

This report presents synthesis results for the past six seasons (2003-2008) of bat monitoring in the Republic of Ireland and Northern Ireland and follows earlier reports (Catto *et al.,* 2004; Roche *et al*., 2005; 2006; 2007; 2008).

2005 saw the first survey square to be completed in Northern Ireland. In 2006 the NIEA funded the monitoring of three squares in Northern Ireland, and five squares in 2007 and 2008. Results are shown in the present report.

Why Monitor Ireland's Bats?

Irish bats are protected under domestic and EU legislation. Under the Republic's Wildlife Act (1976) and Wildlife (Amendment) Act (2000) it is an offence to intentionally harm a bat or disturb its resting place. Bats in Northern Ireland are protected under the Wildlife (Northern Ireland) Order 1985.

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. Article 11 of the Habitats Directive requires member states to monitor all species listed in the Habitats Directive and Article 17 requires States to report to the EU on the findings of monitoring schemes.

Ireland and the UK are also signatories to a number of conservation agreements pertaining to bats such as the Bern and Bonn Conventions. The Agreement on the Conservation of Populations of European Bats (EUROBATS) is an agreement under the Bonn Convention and Ireland and the UK are two of the 32 signatories. The Agreement has an Action Plan with priorities for implementation. One of the current priorities is to produce guidelines on standardised bat monitoring methods across Europe.

Whilde (1993), 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. Two Irish species, the lesser horseshoe bat and the Leisler's bat (*Nyctalus leisleri*), were assigned IUCN European threat categories by Hutson *et al.* (2000) (VU A2c and LR: nt, respectively). VU A2c indicated 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 was formerly categorised as

LR (lower risk): nt (near threatened). The conservation status of bats in Ireland and Europe has been recently updated. The threat level for the lesser horseshoe bat is now described as near threatened for Europe and the European States (Temple and Terry 2007), but within Ireland its population is considered to have good prospects (NPWS 2007). The status of the European Leisler's bat population has been changed from nt to Least Concern (Temple and Terry 2007) and within Ireland it is considered to have good prospects (NPWS 2007). This species is still, however, infrequent in the rest of Europe compared with Ireland where it is quite common.

Despite high levels of legal protection for all species, however, until 2003 there was no systematic monitoring of any species apart from the lesser horseshoe bat. This Car-based Bat Monitoring Scheme, the All Ireland Daubenton's Bat Waterways Survey which began in 2006 (e.g. Aughney *et al.*, 2007) and the Brown long-eared bat Roost Monitoring Scheme (Aughney and Roche, 2008) are helping to redress the imbalance and ensure countrywide coverage and monitoring of a number of species including our important Leisler's bat.

Definite conclusions from a monitoring project based on the road network, such as a car-based bat monitoring scheme, 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. Some caution is needed in doing this since population trends in a non-random sub-sample of available habitats will not necessarily be representative of the population as a whole (Buckland *et al.*, 2005). Further work to assess the degree of bias in the roadside habitats may therefore be needed before extrapolating to other habitats.

Red and Amber Alerts

Under the Habitats Directive, Member States are required to identify species declining at >1% per year. Such a decline would put a species into the "red" category. However, at this stage, assessing trends to this level of accuracy with the current data set would not be statistically sound. It may be feasible to address this requirement in the future when more data has been gathered.

Other standard measurements of population trends are widely used. 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 by 2.73% per annum 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 (and better, if possible) to meet these Alert levels. The 2005 report (Roche *et al*., 2006) included detailed analyses of the sensitivity achieved by the car-based approach and power analysis (see Glossary) to evaluate alternative approaches for the future. Power analysis, has been revisited for the present synthesis report.

The Importance of Ireland's Road Network for Bats

Ireland's small roads, most of which are lined with trees and hedgerows, constitute a major network of connectivity in the landscape. Most European bat species need to fly along linear landscape features, e.g. hedgerows, walls and tree lines, when commuting from roost to foraging site and vice versa (e.g. Fairley 2001; Limpens and Kapteyn 1991). In addition, hedgerow and tree-line habitats along many roads provide a source of insect prey for bats in flight. Bat activity in other habitats adjacent to roadsides – such as rivers, lakes, bogs and forests could also potentially be examined using data from this monitoring scheme.

Road developments can potentially impact negatively on bat biodiversity. Data collected on this programme, when analysed in conjunction with roadside habitat data, will allow more informed decisions on future road network developments to be made, potentially leading to fewer negative environmental impacts associated with such developments. 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

What is a Car-Based Bat Monitoring Scheme?

This protocol is a 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 mapped routes, at a specific time of year, while driving at a prescribed speed. All sounds are recorded for analysis at a later stage.

Overall Aims of 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 and Amber Alert declines in certain Irish bat species' populations.

4. Record other vertebrate wildlife during the survey.

5. To extrapolate information on bat activity within survey squares to determine 'hotspot' areas, and/or areas of high bat diversity.

6. To determine population trends and allow early detection of population declines or highlight increases, if any.

The Aims of this Report

This is the first synthesis report for the car-based bat monitoring scheme. For more detail on the scheme in 2008 see the Irish Bat Monitoring and Recording Schemes: Annual Report 2008 (Aughney *et al.*, 2009).

This report synthesises the data collected from 2003 to present and

- examines the turnover of surveyors, and volunteer time input
- reviews total bat encounters, bat species diversity and abundant and diverse survey squares
- compares relative activity of each species around the island using average data from 2004 to 2008
- looks at population trend data
- revisits Power, to detect both Alert level decreases or population increases.
- includes results of Power analysis on reducing the numbers of transects
- reviews overall 'other vertebrate' data from 2006 to 2008
- makes recommendations on the future of the survey

Interpretation of Bat Encounter Data

The present monitoring project, 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 that 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 unit time or unit distance can 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 a similar loudness. The encounter rate of Leisler's bats, for example, cannot be compared directly with those of common pipistrelles since Leisler's bats are much louder and can be detected at a greater distance compared with common pipistrelles. Trends can be extrapolated over time to determine whether a population is increasing or in decline.

Encounter rates cannot be assumed to directly reflect numbers of bats. It is possible that a single bat could be recorded more than once on the same transect, although methodology has been devised to minimise the risk of repeat encounters from the same individual (Catto *et al.* 2004). For this reason, to consider the encounter rates as a direct indication of individual bats would be inaccurate and overestimate bat numbers. Encounter rates per unit time 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 (e.g. Taylor, 1963; Williams, 1940; Wellington, 1945).
- ***Wind speed and direction***. Aerial insects swarm to the lee of windward (which could determine which side of a road the bat will fly along) (e.g. Lewis and Stephenson 1966) and bats tend to concentrate their activities closer to tree lines during high wind speeds (Verboom and Spoelstra 1999).
- ***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 (e.g. Rydell, 1992).
- ***Timing of survey work***: Seasonal and during the night.
- ***Driving speed* –** the effects of variations in driving speed were examined using field experiments in 2005 and 2006. To reduce the impact of driving speed on results the data is now presented in bat encounters per unit time. See Roche *et al.* (2007) for details.
- ***Irish Bats and Climate Change*** - The impact of man-made greenhouse gas emissions on the world's climate has become of particular concern in the past 10 years and the knock-on effect on vulnerable species of conservation concern is also of importance. For Ireland, continued increases in air temperature around the country, if they occur, are likely to impact on invertebrate availability for Ireland's bat species. In general, aerial insect abundance increases with temperature. Depending on other population limiting factors, which are largely unknown, generalist foragers that are not confined to specific habitats, such as common pipistrelles, may be among the species most likely to show corresponding increases in population as a result of increased air temperature. The effects of climate change on population trends of more selective

foragers, such as those that select specific habitats, will be much more difficult to predict. With increasing temperatures it is possible that new bat species will migrate and become residents in Ireland. Other factors that may affect bats include changing conditions for hibernation, increased storm events and/or windspeeds, increased rainfall and indirect effects such as land use changes, for example.

METHODS

The BCT designed this car-based bat monitoring method in 2003. To date much bat monitoring work has been done in other countries by foot-based trained volunteers (e.g. the UK National Bat Monitoring Programme (NBMP)) but in Ireland, a paucity of trained bat workers until relatively recently has meant that such monitoring work has not been 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. Also, data for three different species can be collected simultaneously.

Training of surveyors has been carried out in summer prior to Survey 1 each year. Each year survey teams carried out surveys of a mapped route within a defined 30km ***Survey Square***. Every route covers 20 x 1.609km (1 mile) ***Monitoring Transects*** each of which is separated by a minimum distance of 3.2km (2 miles). Surveyors are asked to carry out the survey on two dates, one in mid to late July (Survey 1, S1) and one in early to mid-August (Survey 2, S2). Transect coverage begins 45 minutes after sundown. Each of the 1.609km transects is driven at 24km (15 miles) per hour (at night) while continuously recording from a time expansion bat detector on to minidisc. Note that in 2003 surveys were carried out on later dates than in the following years and the survey began 30 minutes after sunset. For this reason, 2003 data is not included in average bat encounter rate analyses.

Minidiscs are forwarded (in pre-stamped and addressed envelopes) to BCIreland for analysis.

Each track is downloaded to Bat Sound™ and calls are 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*). Pipistrelle calls with a peak in echolocation between 48kHz and 52kHz are recorded as 'Pipistrelle unknown' because they could be either common or soprano pipistrelles. Leisler's bat (*Nyctalus leisleri*), a low frequency echolocating species, can also be easily identified using this method. Occasional calls of *Myotis* bats are 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 Brandt's bat (*Myotis daubentonii, M. mystacinus, M. nattereri, M. brandtii*). Occasional social calls of brown long-eared bats (*Plecotus auritus*) are also recorded.

For quality control purposes a number of randomly selected .wav files are forwarded each year to Jon Russ of The BCT for comparative analysis.

Statistical analysis

For overall yearly trends, a Generalised Linear Model (GLM) with a Poisson error distribution (see Glossary) has been applied to the data. Confidence intervals are generated by bootstrapping at Survey Square level (Fewster *et al*., 2000, see Glossary and Appendix I), as used in GAM analysis (see Glossary and Appendix I). This approach essentially means that the number of encounters per survey square is modelled using log of the total number of recording intervals as an offset (Offset see Glossary) but allows use of a Poisson error distribution.

Bat diversity has also been examined using Simpson's Index of Diversity.

The Power of the data to detect Amber and Red alert declines has been re-examined, as well as power to detect upward trends. Power to detect downward trends with lower numbers of transects is also examined, with a view to reducing survey time for future surveys.

Detailed methodology is given in Appendix I.

Other Vertebrates

Other vertebrates were also recorded by surveyors. From 2006 onwards surveyors were asked to note all vertebrates including cats on their record sheets. In addition, observers had the facility to record whether each specimen was living or dead and whether each was observed during or after the transect. This means that recorders were observing living and dead vertebrates, other than bats, along a 93km (58mile) route on each survey evening.

RESULTS

Volunteers

Training of volunteers is generally carried out in an informal way using a powerpoint presentation, demonstrating the use of the equipment and listening to a training CD. Training is carried out in a mutually agreed venue in June, prior to the first survey. Since many of the volunteers have now completed the survey for several years running, training courses are generally targeted at new recruits.

In total, from 2004 to 2008, 124 individuals have taken part in the car-based bat monitoring survey. Fifty of these are staff of the NPWS, 17 staff of the NIEA and the remainder have been members of Bat Conservation Ireland and willing friends and family members. Between 60 and 70 individuals carry out the survey work on a yearly basis. On average, approximately 36% of individuals who participate in the survey in a given year do not participate the following year (see Figure 1). However, core surveyors or team leaders, who are responsible for the survey equipment and act as the contact person, tend to be more likely to repeat the survey year on year. On average just 17% of team leaders (or 6 out of 25 individuals) do not repeat the survey in the following year.

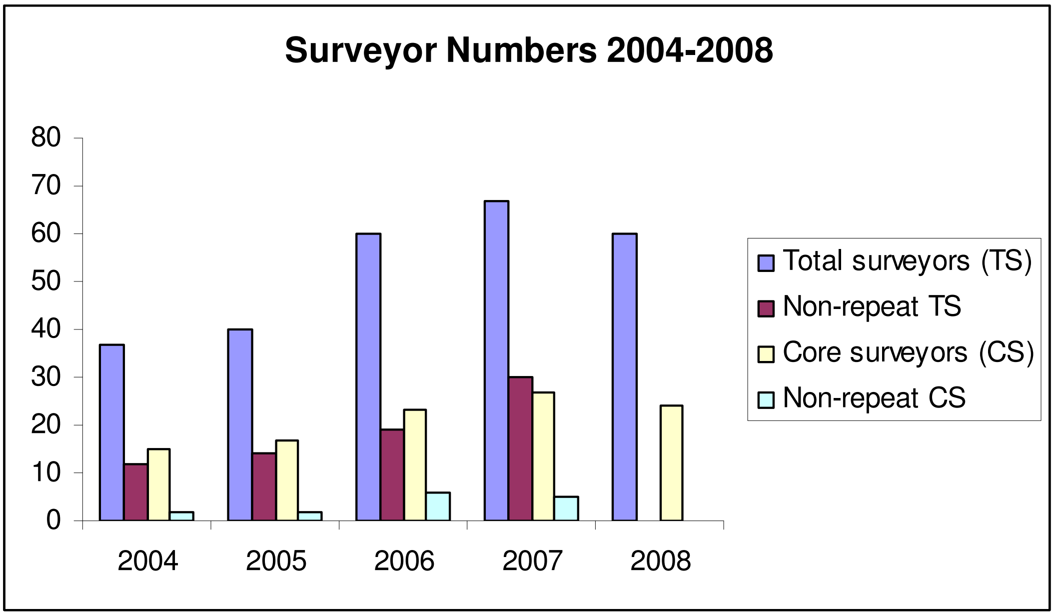


Figure 1: Numbers of volunteers taking part in the car-based bat monitoring survey from 2004 to 2008. Purple bars show number of individuals who did not repeat the survey in the following year. Green bars show core surveyors, who are responsible for equipment and act as contact, who did not complete the survey in the next year.

For certain squares, recruiting volunteers has proven more difficult where there are no bat workers currently residing or wildlife officers do not have sufficient time or specific bat interests. In such squares the turnover of volunteers has been higher than the average elsewhere because surveyors who undertake the work inevitably have to travel to the survey area from some distance away.

Very few surveyors, who train in the methodology, take a box of equipment and commit to carrying out the work, fail to carry out at least one survey. Generally, just one team out of the 28 (4%) do not do the survey at all in any given year.

The survey represents a considerable input of voluntary time - each survey takes approximately 240 minutes to complete (see Table 1). Therefore, in 2008, for example, when 49 surveys were completed, approximately 400 hours of volunteer time were spent on the survey.

Table 1: Average time taken to complete the survey and monitoring transect, per year.

Year	**Average time to complete survey (min)**	**Average time to complete transect (sec)**
2004	233	273
2005	237	280
2006	243	263
2007	240	259
2008	236	242

The mean time taken to complete a monitoring transect (1.609km/1mile) varies between survey routes. As the time expansion detector system only samples for 1/11th of the time, there was an average total sampling time of 22 seconds per monitoring transect in 2008. Also, for every monitoring transect covered 0.146km (0.091 miles) were actually surveyed (i.e. 1/11th of the distance).

Squares Covered 2003-2008

Seven teams participated in the 2003 pilot scheme and 17 survey routes were surveyed in 2004. Twenty one squares were surveyed in 2005. An additional five squares were surveyed in 2006, bringing the total number of surveyed squares to 26 throughout the island. Equipment for 28 squares was disseminated in 2007 and 2008. Surveys were carried out in 27 of these in both years.

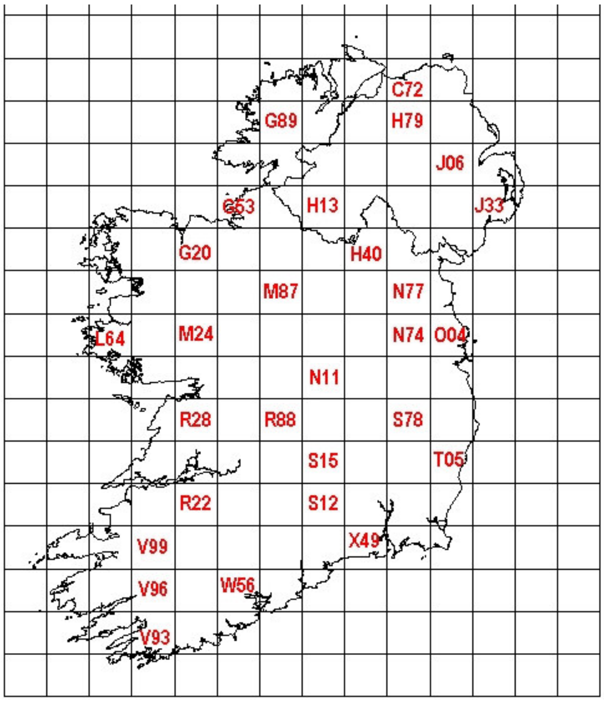


Figure 2: 30km squares in which surveys have been carried out from 2003. Seven of the above squares were surveyed in 2003 and gradually larger numbers have been surveyed year on year. The letter and numbers refer to the south western-most corner Ordnance Survey grid reference.

Survey work is carried out from mid-July to the beginning of August and a repeat survey is carried out from the beginning of August to mid-August.

Of the 27 squares that were surveyed in 2008, 22 of these were repeated (a total of 49 night's field work), see Figure 2. In total, between 998km (2004) and 1576km (2008) of monitoring transects have been driven each year. Each year a number of equipment problems or other difficulties arise, for example bad weather, that result in surveys being abandoned or poor quality data that cannot be included in the dataset. In general, the quality of data collected from 2005 onwards has been very good, however.

In total, 13606 bat encounters have been recorded since 2003. The total number of bats encountered has increased yearly from 378 in 2003 to 3280 in 2008. See Table 2 to compare yearly totals.

Table 2: Total number of bat encounters and total number of 1.6km transects surveyed per year.

Year	Total No. Bats	Transects
2003	378	180
2004	2031	576
2005	1691	608
2006	3212	887
2007	3014	889
2008	3280	927
TOTAL	**13606**	**4067**

Note that the total number of bat encounters does not necessarily equate to that number of individual bats since bats may be recorded more than once during a transect and/or recorded in July and again in August.

Dataset Generated

Table 3 below shows raw bat encounter data, with encounters per 1.6km transect. Note that the results in Table 1 of both Roche *et al.* (2005) and Roche *et al.* (2006) showed erroneous information which is corrected in Table 3 below. Figure 3 shows proportions of each species or species group encountered, from 2004 to 2008 illustrated as a pie-chart. The common pipistrelle is the most abundant species. Soprano pipistrelle and Leisler's bat are equally represented with 20% each of the total bat encounters. An additional 8% of bat encounters cannot be ascribed to either the common pipistrelle or soprano pipistrelle and are therefore recorded as 'unknown pipistrelles'. *Myotis* spp., Nathusius' pipistrelles and brown long-eared bats are rarely encountered.

Table 3: Raw bat encounter data, per 1.609km/1 mile transect, not corrected to encounters per km or per hour, Car-based Bat Monitoring Scheme 2003-2008. Average number of bats reflects the average number of bat encounters observed during each 1.609km/1 mile transect travelled. Total Number of Transects (n): 2003 n=180; 2004 n=577 for pipistrelle, *Myotis* spp. and total bats, n=597 for Leislers[1]; 2005, n=608; 2006 n=887; 2007 n=889; 2008 n=927, for all species. Note that the detector records for just 1/11th of the time spent surveying so to determine the actual number of bat encounters per km this must be divided by 0.146 (the total distance sampled for each 1.609km transect).

Average encounters per 1.6km transect	**Common pipistrelle**	**Soprano pipistrelle**	**Pipistrelle unidentified**	**Myotis spp.**	**Leisler's bat**	**Nathusius' pipistrelle**	**Total Bats**
2003	1.294	0.478	N/a	0.039	0.289	0.000	2.100
2004	1.905	0.695	0.443	0.050	0.511	0.000	3.621
2005	1.344	0.574	0.266	0.035	0.544	0.001	2.781
2006	1.701	0.652	0.271	0.029	0.892	0.033	3.620
2007	1.77	0.639	0.253	0.036	0.631	0.015	3.390
2008	1.686	0.768	0.294	0.029	0.739	0.006	3.537

[1] More data was available for Leisler's than other species in this year due to a detector problem in one survey square which caused sounds at frequencies above 30kHz to be non-analysable.

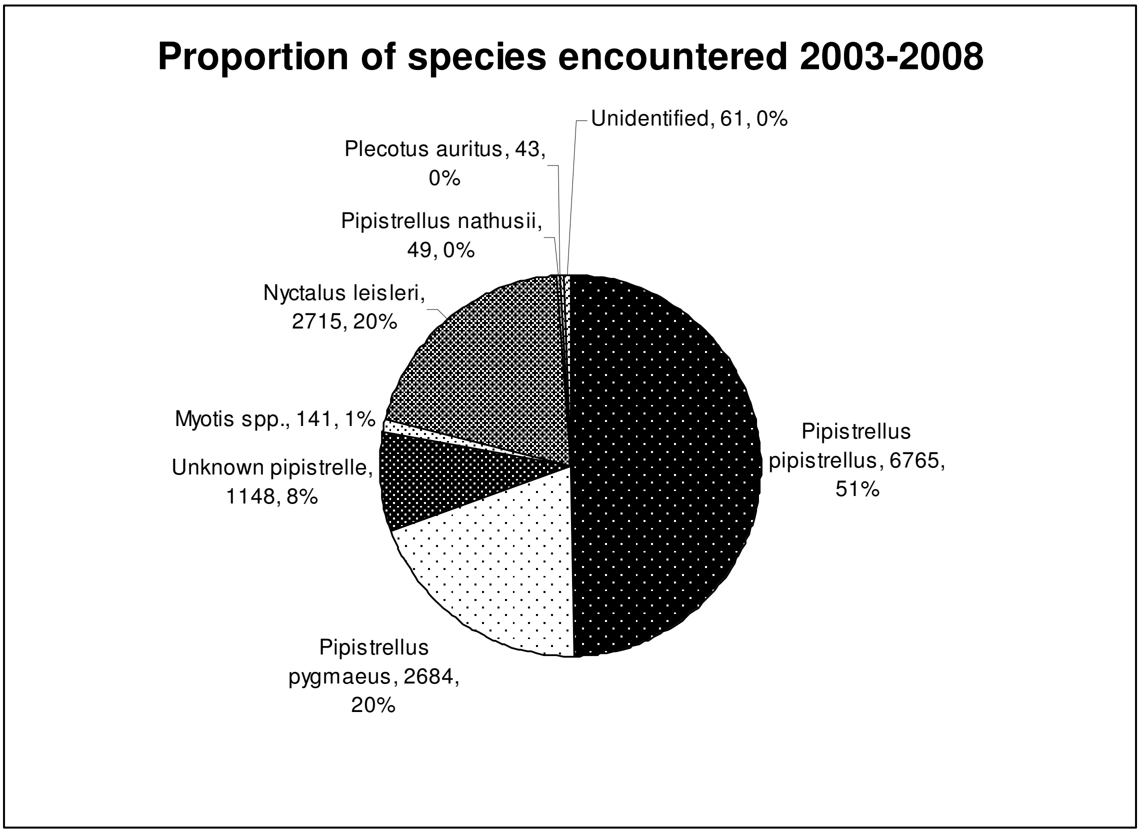


Figure 3: Proportion of species encountered during the survey, 2003-2008. Total number of bat encounters: 13,606. Excepting social calls of Leisler's bats and brown long-eared bats, which are unlikely to be mistaken for those of other species, bat social calls were noted during sonogram analysis but are not included in the above pie chart or in any statistical analyses.

Activity Hotspots and Diversity

High Abundance

Average encounter rates for particular survey squares are subject to a high level of random variation during each survey. In addition, some squares (such as those in Northern Ireland) have only recently been added to the survey so a lower number of surveys have been conducted in these compared with some of the squares further south. However, as a rough exercise in determining overall encounter rates for different squares, the total number of bat encounters per hour was averaged for each square from 2004 to 2008. For some squares a full dataset is available, therefore N=10. Other squares have been surveyed less often so in most cases N ≥ 4. The following map (Figure 4) illustrates a gradation in overall encounter rates across the island, with higher encounters in the south west and a couple of midlands squares, and decreasing encounters in the north and north-west. The average total bat encounter rate per hour for all squares from 2004 to 2008 was 45.20hr^{-1}. Since the common pipistrelle is the most commonly encountered species, accounting for over 50% of all bats recorded, this map is heavily biased towards squares with the highest encounters of this species. Indeed decreasing encounter rates with higher latitudes reflects the relative activity distribution of the common pipistrelle (e.g. see Figure 7).

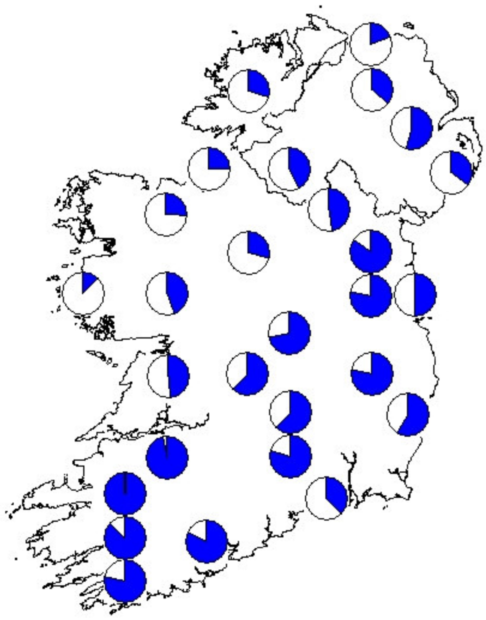


Figure 4: Survey squares with total bat encounter rates (per hour) from 2004-2008 expressed as a proportion of the maximum total encounter rate (Square V99, 81.28hr^{-1}). Pies represent average data from all surveys available, N=4-10 depending on the square. The overall average rate of total bat encounters for 2004 to 2008 was 45.20hr^{-1}.

Squares V99 and R22 have particularly high encounter rates. Lowest average encounter rates, as may be expected, are found in squares along the northern and western seaboards; L64 and C72, for example. Square X49 continues to show somewhat anomalous results with consistently low encounter rates, despite its location in the south of the island.

Simpson's Index of Diversity

In order to account for bias towards common pipistrelle abundance, bat diversity has also been examined. Simpson's Index was applied to the bat encounter data (per hour) for each species in each square.

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

where:

n=total encounter rate of a particular species or species group

N=total encounter rate of all species.

The results, shown as Simpson's Index of Diversity (1-D), are illustrated using pie charts in Figure 5. The formula 1-D is used because higher numbers reflect higher bat diversity, with 1 indicating maximum diversity and 0 species uniformity. For Simpson's Index of Diversity the number reflects the probability that any given bat encounter will be a different species from the previous bat encountered. See Appendix II for the full list of Simpson's Index results for all squares.

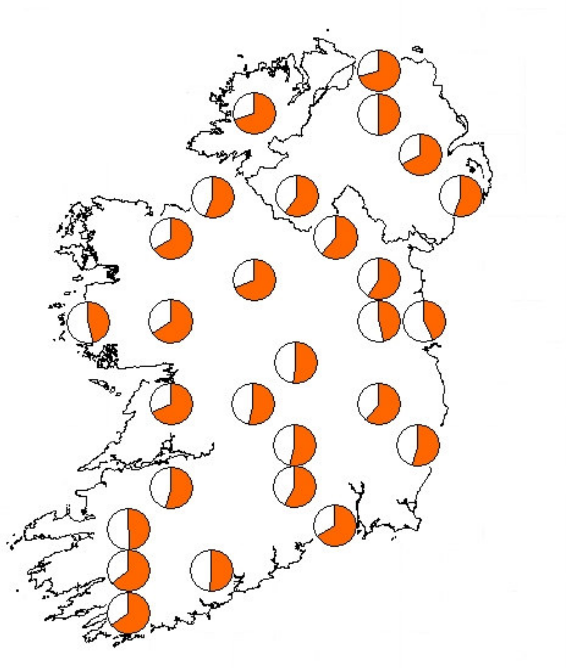


Figure 5: Survey squares with Simpson's Index of Diversity (1-D) shown in orange. High proportion of orange colour indicates high diversity, or a high probability that any given bat will be a different species from the previous bat encountered.

The results mainly show that low encounter rate squares are the most diverse, i.e. in low encounter rate squares, species abundance is more evenly spread than in areas where bats are very abundant. Examples of squares with low encounter rates but high diversity are C72, G20 and G89.

Abundance and Diversity Combined

Squares with an average total bat encounter rate of $>60hr^{-1}$ combined with a Simpson's Index of Diversity (1-D) score ≥0.6 highlights three squares in particular where **both** diversity and abundance are consistently high: S78, V96 and V99. These squares are illustrated in blue in Figure 6. Other squares that achieve total bat encounters rates $>55hr^{-1}$ and a Simpson's Index of Diversity (1-D) ≥0.5 are shown in yellow. All highlighted squares are situated in the south west, midlands and east of the country.

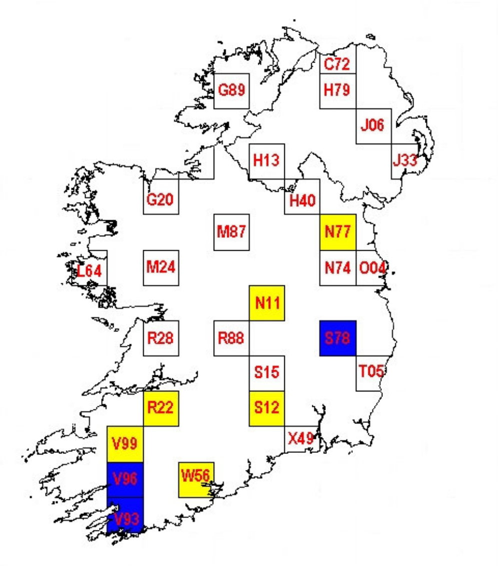


Figure 6: Overall bat abundance (average total bat encounter rate) and Simpson's Index of Diversity, combined.

Bat encounter rate $>60hr^{-1}$ **and** 1-D≥0.6.

Bat encounter rate $>55hr^{-1}$ **and** 1-D≥0.5.

Common pipistrelle, *Pipistrellus pipistrellus*

Common pipistrelles have been the most frequently encountered species during the monitoring scheme in all survey years to-date. In L64, Connemara, no common pipistrelles have been confirmed from 2005 to 2008, the four years when surveys have been carried out in that square. This square is illustrated in blue in Figure 7. Encounter rates with this species are generally lower in northern and western squares, with some exceptions, for example, X49 and S15, which are southern squares where few common pipistrelles have been recorded. Low levels of activity are illustrated in brown in the following map. Survey squares illustrated in red have the highest average common pipistrelle encounter rates: N77, N74, R22, V99 and W56.

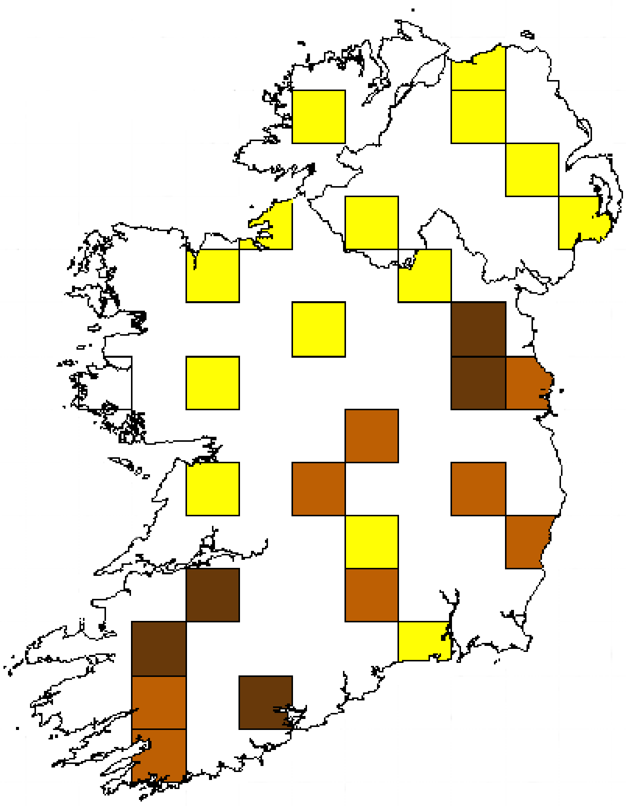


Figure 7: Survey squares colour coded according to common pipistrelle encounter rates (per hour). Map represents data from all surveys from 2004 to 2008, where n=4-10. The overall average rate of common pipistrelle encounters for all squares in all years is 24.2hr^{-1}.

Absent.

Encounter rate >0≤20hr^{-1}

Encounter rate >20≤40hr^{-1}

Encounter rate >40hr^{-1}

Common Pipistrelle Yearly Activity

Figure 7 below shows mean common pipistrelle passes per survey per year, adjusted to represent the situation if all surveys had the average number of 0.32sec recordings.

Results of this GLM model, in which encounter rates are adjusted to allow for site effects, show that 2007 had the highest average common pipistrelle encounters per survey of all survey years since 2003.

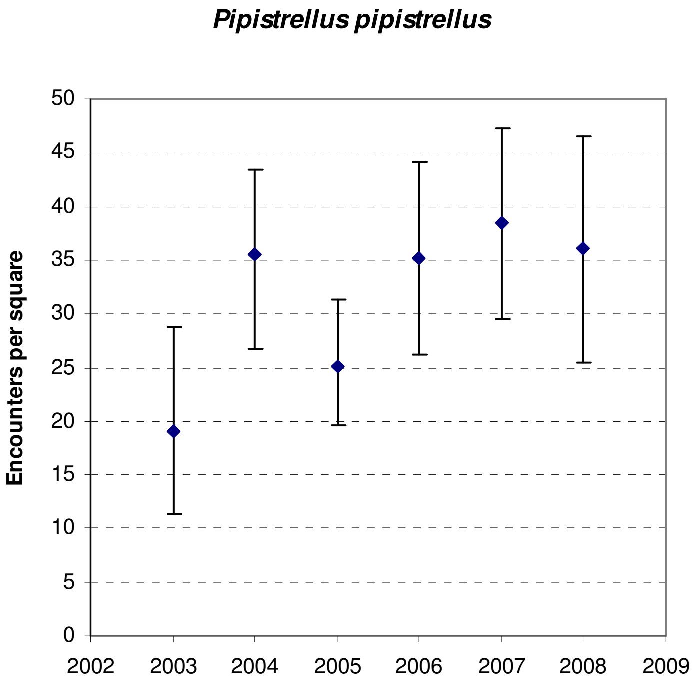


Figure 8: Results of the GLM model for encounters of common pipistrelles per survey. Bars are 95% bootstrapped confidence limits.

In 2003, lower encounter rates may have arisen from later survey dates, lower number of survey squares and an earlier starting time. It is worth noting that the graph (Figure 8) shows the encounter rate for 2004 as lower than 2007. While this seems at odds with the results shown in Table 3 the discrepancy arises as a result of the different squares surveyed in 2004 compared with 2007. In 2007, more squares in the north were included in the data compared with 2004 when squares were confined to the Republic and, even then, mainly the south and midlands were surveyed. The GLM model adjusts the encounter rate to account for these site effects, hence the encounter rate for 2004 appears lower than what was actually recorded.

Common Pipistrelle Population Trend

A simple linear model was fitted to the GLM data above. For common pipistrelles the lower and upper bootstrap confidence limits are both positive (see Table 4). This could, with caution, indicate an increase in common pipistrelle encounters over time. Trends will only be determined more accurately with more years' data, however.

Table 4: Slopes and 95% confidence limits for a linear model of trend. Confidence limits are formed by bootstrapping at the site level. Slopes relate to the population change on the logarithmic scale per year.

	P. pipistrellus
Slope	0.07
95% lower	0.01
95% upper	0.13

Soprano pipistrelle, *Pipistrellus pygmaeus*

The soprano pipistrelle was the second most frequently encountered species during the car-based bat monitoring scheme in all survey years, except 2006.

Particularly high average encounter rates have been observed in some western squares – M24, R22 and V96, as well as H40 on the Cavan-Tyrone border. The soprano pipistrelle was the only pipistrelle species confirmed in L64 in all years when surveys have been carried out there. See Figure 9 for a graphic comparison of encounter rates in different survey squares during each survey. Low to medium encounter rate squares are widely distributed but appear to show something of an eastern bias. Seven out of the nine highest encounter rate squares occur in the west of the island. Lowest encounter rate survey squares occur in the extreme north and the east.

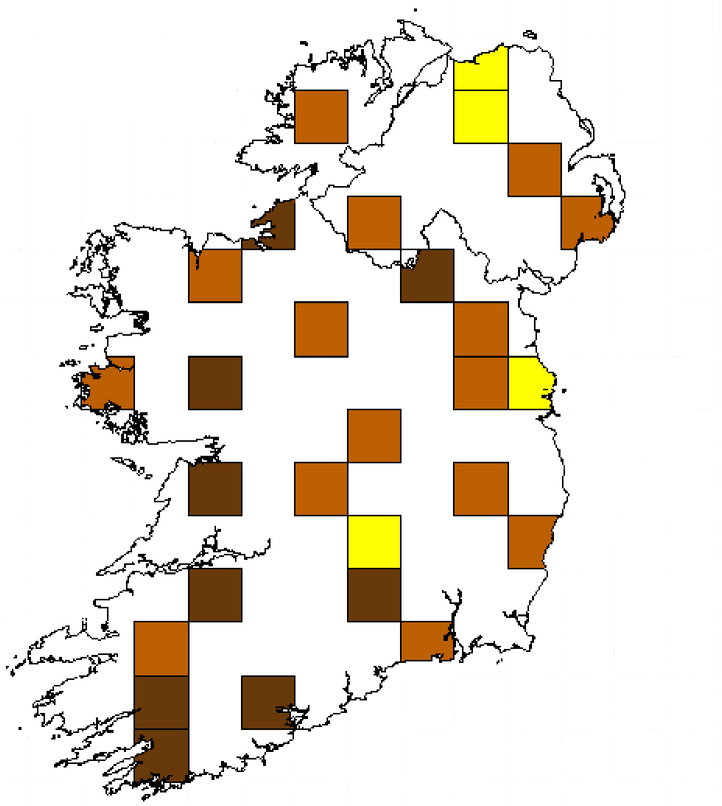


Figure 9: Survey blocks colour coded according to soprano pipistrelle encounter rates (per hour). Map represents data from all surveys from 2004 to 2008, where n=4-10. The overall average rate of soprano pipistrelle encounters for all squares in all years is $9.76hr^{-1}$.

Absent.

Encounter rate/km $>0\leq6hr^{-1}$

Encounter rate/km $>6\leq12hr^{-1}$

Encounter rate/km $>12hr^{-1}$

In 2006 REML modelling indicated that there was a not quite significant negative relationship between encounter rates and grid reference eastings (p=0.09) (Roche *et al*. 2007).

Soprano Pipistrelle Yearly Activity

Figure 10 shows mean soprano pipistrelle encounters per survey, adjusted to represent the situation if all surveys had the average number of 0.32ms recordings. The encounters per survey are also adjusted to account for site effects.

The encounter rate for soprano pipistrelles was higher in 2008 than in any other survey year. In 2003, particularly low encounter rates may have arisen from slight differences in methodology as described for common pipistrelles above. It is worth noting that the graph (Figure 10) shows the encounter rate for 2007 as higher than 2006. While this seems at odds with the results shown in Table 3 the discrepancy arises as a result of the different squares surveyed in each year. In 2007, more squares in the north were included in the data compared with 2006.

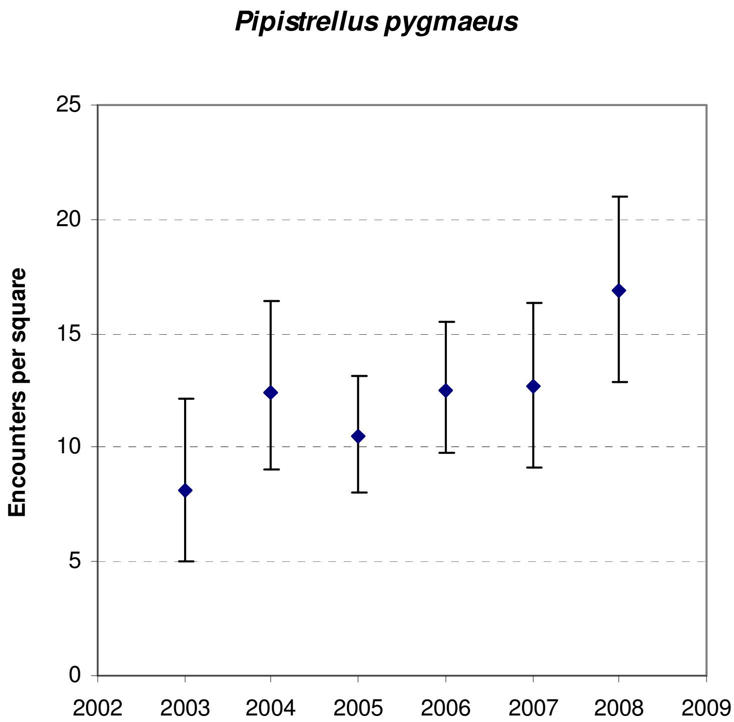


Figure 10: Results of the GLM model for encounters of soprano pipistrelle per survey. Bars are 95% bootstrapped confidence limits.

Soprano Pipistrelle Population Trend

Trends in soprano pipistrelle abundance are still not apparent. When a simple model with a linear trend over time is applied to the data, the lower bootstrapped confidence limit is exactly zero. This implies an increase of borderline significance. However, more data is required before trends can be definitively deduced.

Table 5: Slopes and 95% confidence limits for a linear model of trend. Confidence limits are formed by bootstrapping at the site level. Slopes relate to the population change on the logarithmic scale per year.

	P. pygmaeus
Slope	0.10
95% lower	0.00
95% upper	0.20

Leisler's bat, *Nyctalus leisleri*

Leisler's bats have been the third most frequently encountered species during the monitoring scheme in all survey years to-date, except 2006 when the species was the second-most common. This species has been encountered in all survey squares. Low levels of activity are illustrated in brown in the following map (Figure 11). Encounter rates with this species are generally lowest in north western squares. Survey squares illustrated in red have the highest average Leisler's bat encounter rates: H79, J06, N77, S12, S78, V93, V96 and V99. These squares are located mainly in the south-west, south and east of the country.

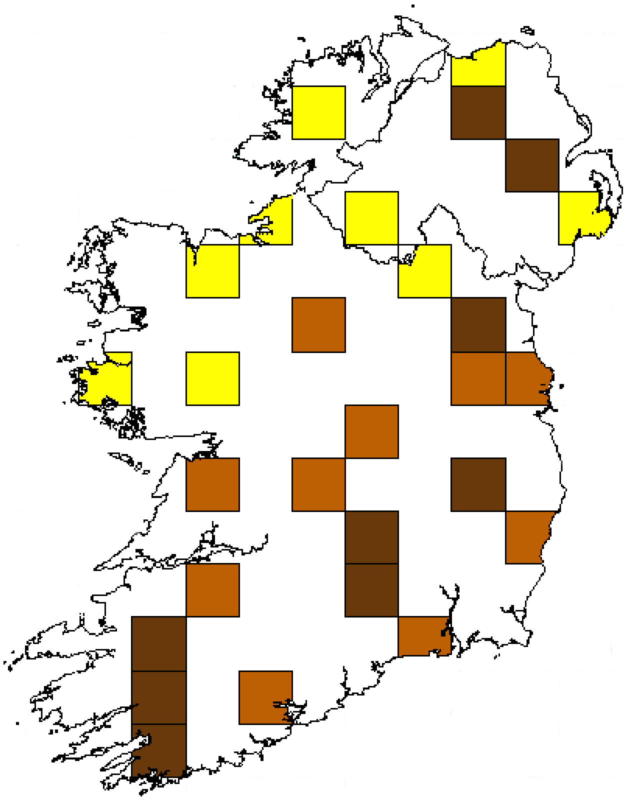


Figure 11: Survey blocks colour coded according to Leisler's bat encounter rates (per hour). Map represents data from all surveys from 2004 to 2008, where n=4-10. The overall average rate of Leisler's bat encounters for all squares in all years is 10.39hr^{-1}.

Absent.

Encounter rate/km >0≤6hr^{-1}

Encounter rate/km >6≤12hr^{-1}

Encounter rate/km >12hr^{-1}

Leisler's Bat Yearly Activity

Figure 12 shows mean Leisler's bat encounters per survey, adjusted to represent the situation if all surveys had the average number of 0.32ms recordings. The mean is also adjusted to allow for site effects.

The year 2006 had higher average Leisler's encounters per survey than any survey year to date. In 2003, particularly low encounter rates may have arisen from slight differences in methodology as described for common pipistrelles above.

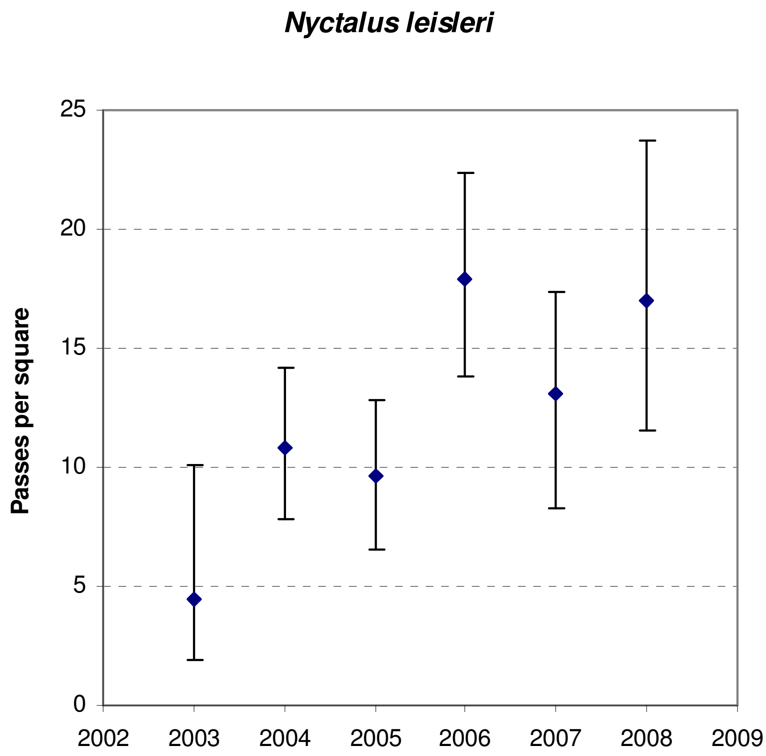


Figure 12: Results of the GLM model for encounters of Leisler's bats per survey. Bars are 95% bootstrapped confidence limits.

Leisler's Bat Population Trend

When a simple model with a linear trend over time is applied to the data shown in Figure 12 above, both bootstrapped confidence limits are above zero. This implies an increase in Leisler's bat population over time. This will only be verifiable in future survey years, however, as more data are collected.

Table 6: Slopes and 95% confidence limits for a linear model of trend. Confidence limits are formed by bootstrapping at the site level. Slopes relate to the population change on the logarithmic scale per year.

	N. leisleri
Slope	0.15
95% lower	0.03
95% upper	0.23

Nathusius' pipistrelle, *Pipistrellus nathusii*

This species was recorded for the first time by the car monitoring scheme in 2005 in square N77, the North-East. This species is known to be resident in Northern Ireland and, while it has been recorded in the Republic, its status there is somewhat unclear.

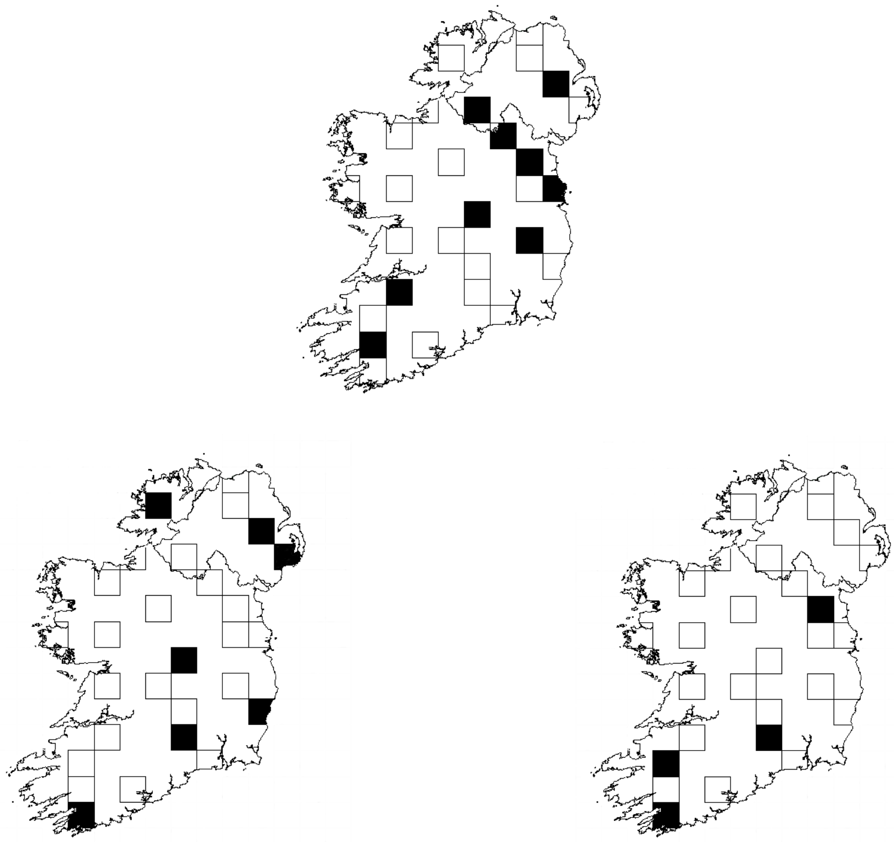


Figure 13: Presence (**black**) / absence (white) of Nathusius' pipistrelle in 2006 (top), 2007 (bottom left) and 2008 (bottom right). Note that some squares indicate absence but were not surveyed in a particular year. Nathusius' pipistrelle has not been recorded in all three years in any survey square, although J06, a stronghold for the bat, was not surveyed in 2008.

The car-based bat monitoring results for 2006 saw a dramatic increase in Nathusius' pipistrelle encounters across the island. While some of these occurred in newly surveyed squares in Northern Ireland, where Nathusius' pipistrelles may be expected to occur, additional recordings of the species were made in squares that had been surveyed for a number of years prior to 2006 but where the species had not previously been recorded. R22, S78, T05, N11 and V96 were among the first squares mapped and surveyed in 2003 and most were surveyed every year since, but Nathusius' pipistrelle was recorded in each in 2006 for the first time.

In general Nathusius' pipistrelle has been recorded from the north, east and south-west with no records in western squares such as L64, M24 or G20.

Nathusius' Pipistrelle Yearly Activity

Figure 14 shows mean Nathusius' pipistrelle encounters per survey, adjusted to represent the situation if all surveys had the average number of 0.32ms recordings. The encounters per survey are also adjusted to account for site effects. Highest encounter rates were recorded in 2006.

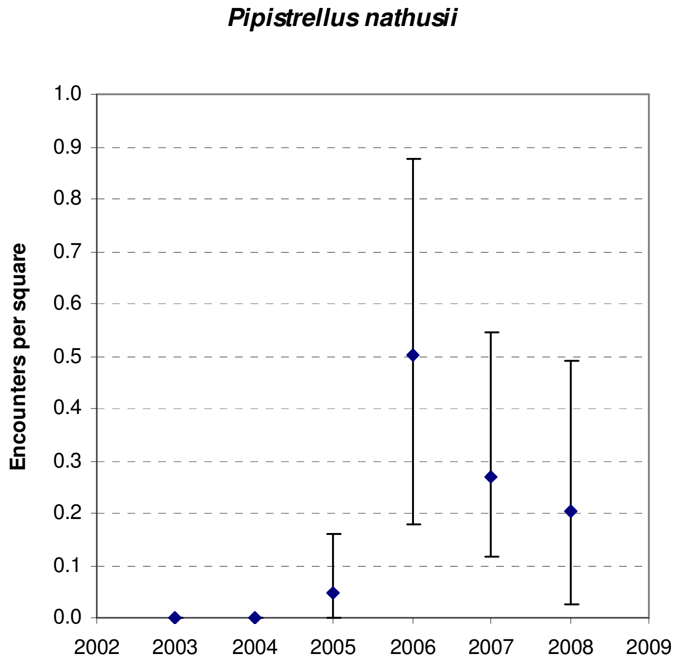


Figure 14: Results of the GLM model for Nathusius' pipistrelle encounters per survey. Bars are 95% bootstrapped confidence limits.

Nathusius' Pipistrelle Population Trend

Data collected thus far shows an increase to 2006 followed by a decrease to 2008 levels. While data is very sparse for this species, the trend may be quadratic. Certainly, when a simple model is fitted to the data, with a linear trend over time, the lower bootstrapped confidence interval for Nathuisus' pipistrelle is negative (see Table 7). This indicates that the species may not currently be on the increase, as was thought in previous reports (e.g. Roche *et al*. 2007).

Table 7: Slopes and 95% confidence limits for a linear model of trend. Confidence limits are formed by bootstrapping at the site level. Slopes relate to the population change on the logarithmic scale per year.

	P. nathusii
Slope	0.29
95% lower	-0.02
95% upper	0.52

Myotis bats

Myotis bats have been recorded from all but six of the 28 survey squares (see Figure 15). Locations of *Myotis* bat records from the car-based bat monitoring scheme are widely distributed throughout the country.

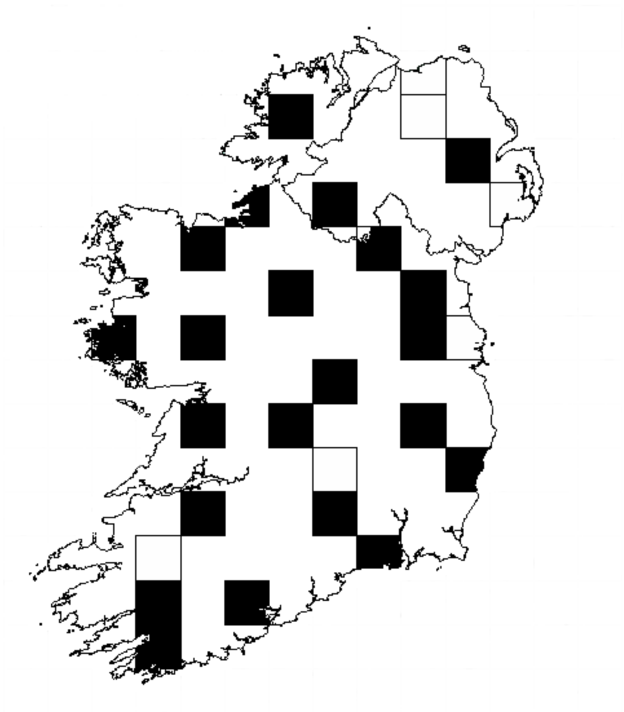


Figure 15: Survey blocks colour coded according to *Myotis* bat presence/absence, 2004 to 2008. Locations where *Myotis* bats have been recorded are highlighted in **black**. White squares indicate an absence of records to-date.

Myotis bats occur in such low numbers during the car-based bat monitoring survey that little can be determined about trends, due to the large error bars surrounding each yearly estimate (see Figure 16). A simple model fitted to the *Myotis* data with a linear trend over time does not give any indication of trends either since the bootstrapped confidence intervals encompass zero. Should trends in *Myotis* encounter rates become apparent in time, these should be treated cautiously since the results for *Myotis* bats are likely to comprise a number of species.

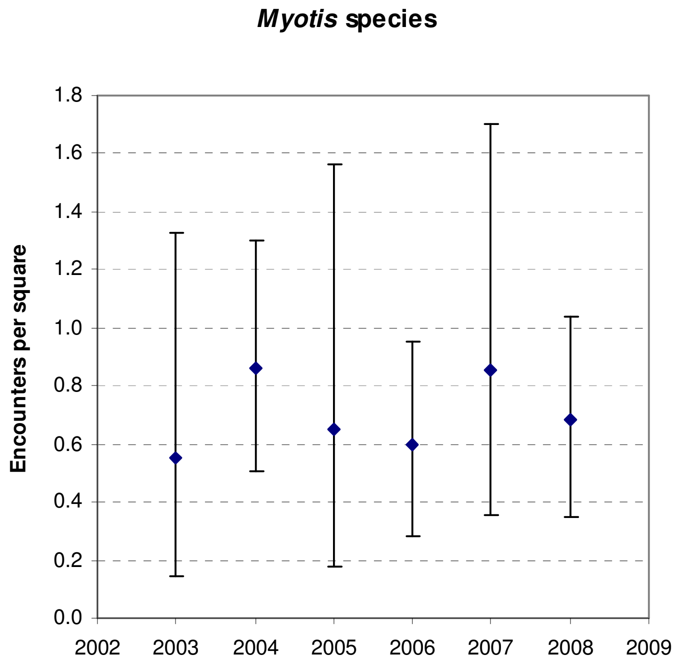


Figure 16: Results of the GLM model for *Myotis* encounters per survey. Bars are 95% bootstrapped confidence limits.

Brown long-eared bat, *Plecotus auritus*

This species was encountered for the first time by the car monitoring scheme in 2005. The species is largely undetectable by the scheme due to its quiet echolocation calls. However, it does occasionally produce social calls of higher amplitude (loudness). Locations of Survey Squares where the species has been recorded are shown in Figure 17.

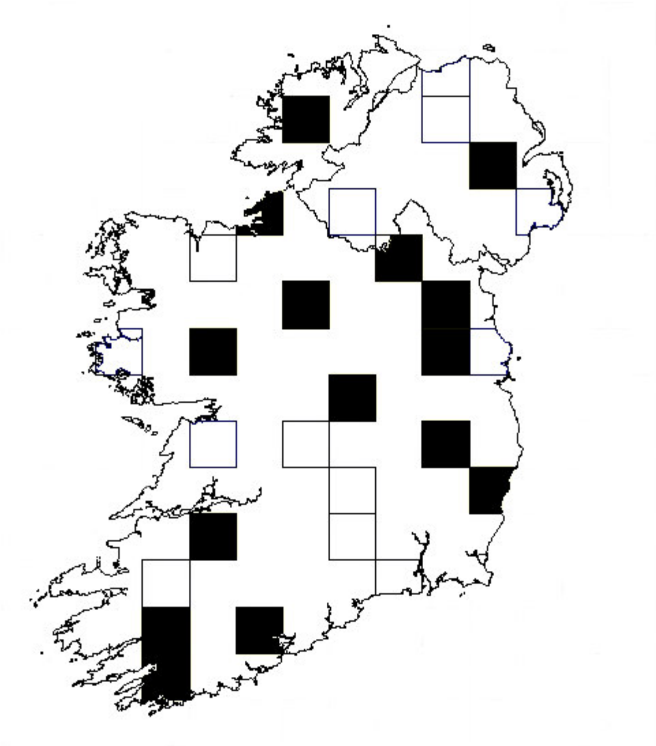


Figure 17: Survey blocks colour coded according to brown long-eared bat social call presence/absence, 2004 to 2008. Locations where brown long-eared bats have been recorded are highlighted in **black**. White squares indicate an absence of records.

This species is monitored using a separate scheme of counting individuals at roosts, see Aughney *et al.* 2009.

Power Analysis

Detecting Declines or Increases

The Power of the data to detect Red or Amber Alert declines, or population increases, was investigated using all available data. Power analysis results, using two surveys per year with varying numbers of squares are shown in Tables 8 and 9. Individual values are subject to estimating errors so it is necessary to take a broad view of the effectiveness of different numbers of transects, comparing for a range of scenarios. The differences from previous results (see Roche *et al*., 2006) are generally small, with some minor reductions in the time taken.

Table 8: Number of years (including the extra years needed at either end of the GAM curve) to achieve 80% power for Amber and Red Alert Declines (i.e. 25% or 50% decline over 25 years). [Whilst the number of years must be an integer in reality results are shown here with one decimal place to aid comparisons. Standard errors are 1.0 years for most estimates, but will be larger for values over 28 years (shown in italics). All figures use 20 one mile transects per square.]

	Common pipistrelles		**Soprano pipistrelles**		**Leisler's**	
No. of Squares	**Amber**	**Red**	**Amber**	**Red**	**Amber**	**Red**
10	21.9	11.7	*31.6*	12.8	*31.3*	13.4
15	18.8	10.9	24.6	12.6	21.2	13.7
20	15.9	8.2	19.4	11.2	22.6	12.3
25	14.3	6.7	19.2	9.7	19.8	11.8

Power analysis was also carried out on the effect of doubling of numbers over 25 years (Table 9). Since the GAM models are additive on a logarithmic scale, the power for a doubling of the population could be expected to be roughly the same as for a halving (i.e. the same as the red alert which is a 50% reduction over 25 years). This does appear to be roughly the case; differences are larger for 10 squares, but this result may not be reliable since 10 squares is really too few for the bootstrapping process.

Table 9: Number of years (including the extra years needed at either end of the GAM curve) to achieve 80% power for a 100% increase (i.e. doubling of the population) over 25 years. [Whilst the number of years must be an integer in reality results are shown here with one decimal place to aid comparisons. Standard errors are 1.0 years for most estimates. All figures use 20 one mile transects per square.]

No. of Squares	Common pipistrelles	Soprano pipistrelles	Leisler's
10	12.7	16.5	17.9
15	8.3	12.8	13.3
20	9.1	11.3	12.4
25	7.9	8.2	10.7

Number of Transects

A review of data in Roche *et al.*, (2008) showed that the best way to reduce survey time is to cut down on the number of transects covered rather than cut out the two mile gaps between transects. Power analysis was carried out in summer 2008 (therefore without the data from 2008) to determine what kind of scenario could result in shorter survey times while minimising loss of precision within the data.

Table 10 (a to d) shows the results of this Power Analysis. Rows highlighted in grey show the difference in Power when between 20 and 25 squares are surveyed twice annually, either with 20 or 15 one mile transects.

Table 10: number of years (including the extra years needed at either end of the GAM curve) to achieve 80% power for various scenarios. [Whilst the number of years must be an integer, in reality, results are shown here with one decimal place to aid comparisons. Standard errors are 1.0 years for most estimates, but will be larger for values over 28 years (shown in italics). Note that Table 10a results shown below differ slightly from results shown in Table 9, this is because Table 9 includes 2008 data, which were not available for the analysis shown here.]

a) 20 one mile transects per square

	Common pipistrelles		**Soprano pipistrelles**		**Leisler's**	
No. of Squares	**Amber**	**Red**	**Amber**	**Red**	**Amber**	**Red**
10	18.1	11.2	*33.2*	13.8	*38.2*	15.7
15	15.6	8.6	26.6	11.7	*29.7*	14.4
20	15.0	7.8	20.4	12.4	25.9	14.0
25	14.7	7.6	20.3	9.7	23.5	12.7

b) 15 one mile transects per square

	Common pipistrelles		**Soprano pipistrelles**		**Leisler's**	
No. of Squares	**Amber**	**Red**	**Amber**	**Red**	**Amber**	**Red**
10	18.7	11.9	*37.0*	16.2	*35.4*	17.0
15	16.8	8.9	*28.8*	13.0	*29.9*	13.5
20	14.6	7.8	25.2	13.7	25.6	14.0
25	13.3	7.7	22.7	11.3	25.1	12.8

c) 10 one mile transects per square

	Common pipistrelles		**Soprano pipistrelles**		**Leisler's**	
No. of Squares	**Amber**	**Red**	**Amber**	**Red**	**Amber**	**Red**
10	24.5	9.3	*42.1*	16.8	*>30*	17.4
15	18.5	10.0	*31.3*	13.4	*31.1*	14.5
20	17.4	9.4	27.6	13.7	27.5	14.6

25	15.5	9.8	25.0	12.5	25.4	13.7

d) 5 one mile transects per square

	Common pipistrelles		Soprano pipistrelles		Leisler's	
No. of Squares	**Amber**	**Red**	**Amber**	**Red**	**Amber**	**Red**
10	27.7	13.6	*51.9*	19.1	*61.1*	23.6
15	22.2	12.3	*35.1*	15.7	*37.8*	18.6
20	19.3	12.1	*32.6*	15.8	*33.1*	17.0
25	18.4	9.9	*29.7*	16.1	*31.4*	15.7

Comparing 15 transects (Table 10b) with the current design (Table 10a), it can be seen that there is very little loss of efficiency; most Alerts take only 1-2 more years to detect. Only for soprano pipistrelles with small numbers of squares is there an appreciable increase in the number of years required. For 10 transects, the change in the time required from the full 20 transects is still relatively small for common pipistrelle and Leisler's. Only when the number of transects is reduced down to 5 (Table 10d) does the impact on power become really marked.

OTHER VERTEBRATES

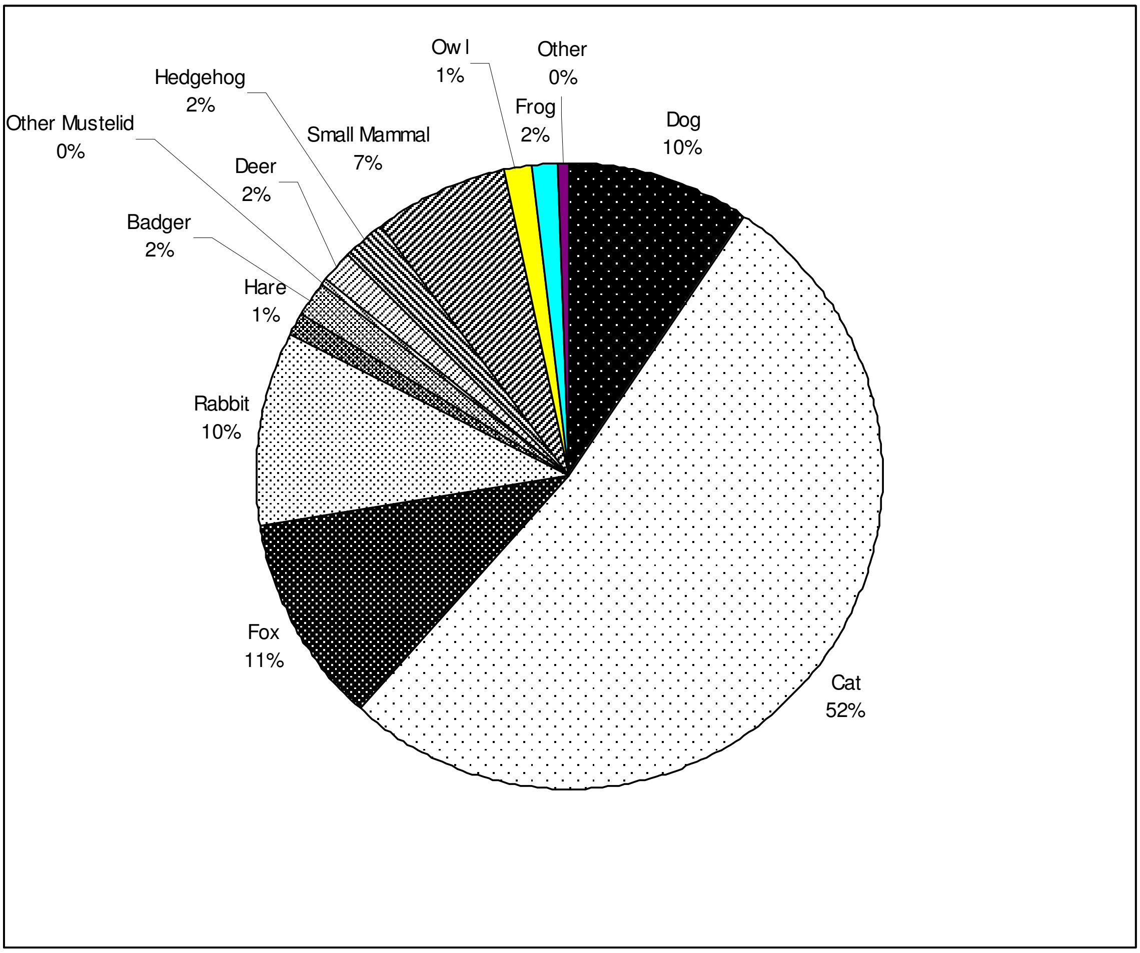


Figure 17: Living vertebrates, other than bats, observed during all surveys 2006-2008 n=1109. Surveys prior to 2006 did not include cats and dogs so results are not included. 'Small mammals' category includes mice, rats, pygmy shrews, voles and unidentified small mammals. The 'Others' category includes horses and birds. The 'Other mustelids' category includes stoat, mink and pine marten.

Surveyors were asked to record living and dead vertebrates other than bats during survey transects in 2004 and 2005. From 2006, recording of other vertebrates was carried out throughout the survey, during and between transects, thus covering far larger areas than in previous years. From 2006 surveyors were also specifically requested to record cats and dogs.

Between 4,100 and 4,600km of roads were surveyed for vertebrates other than bats each year since 2006. Of particular interest from 2006 onwards was the high number of cats observed. Cats constitute 52% of the total living vertebrate records from 2006 to 2008 (see Figure 17). The second most frequently recorded vertebrate is the fox at 11%. Similar numbers of rabbits and dogs are also recorded (10% each). Rare and/or protected species of interest are also occasionally recorded, such as barn owls and pine martens.

Table 11: Number of living and dead vertebrates, other than bats, recorded by surveyors, 2004 onwards.

Year	Living Vertebrates	Dead Vertebrates
2004	62	9
2005	80	4
2006	322	28
2007	383	21
2008	404	29

Trends in encounter rates of other mammals or vertebrates have not been examined to-date. Overall average total encounter rates have increased steadily, from 0.077km^{-1} in 2006, 0.084km^{-1} in 2007 and 0.095km^{-1} in 2008 (see Figure 18).

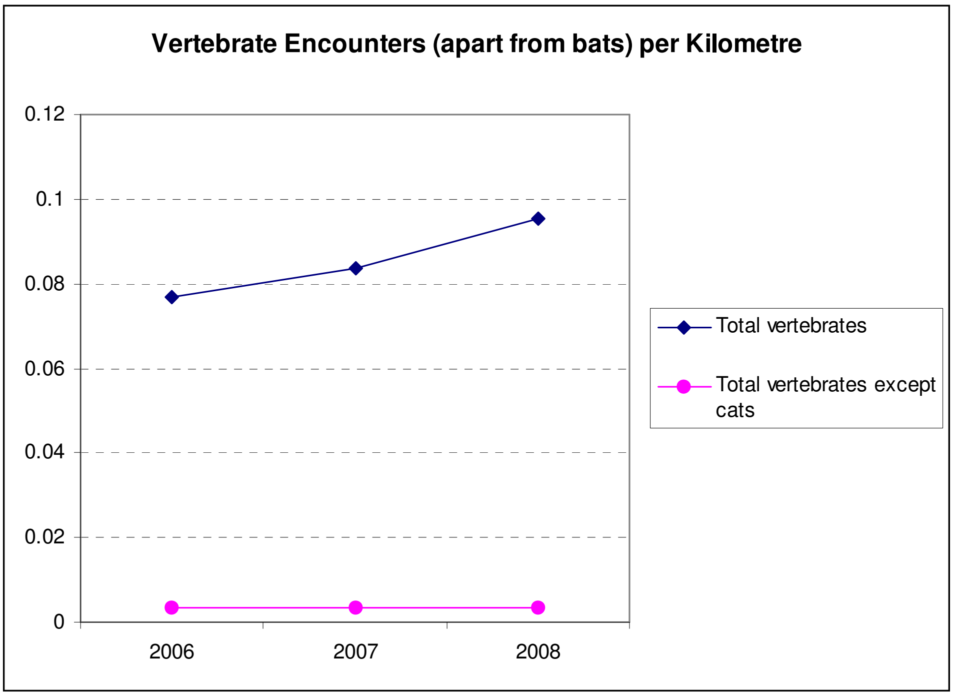


Figure 18: Total vertebrate encounters per kilometre for the years 2006 to 2008 shown in blue. The same data with cat encounters subtracted is shown in pink.

A plot of the same data with the most abundant species, the cat, removed shows that the increasing trend is largely due to the increase in the number of cats observed per kilometre since 2006. The totals for other vertebrates (minus cats), when plotted separately on the same Figure (18) are largely static. Further year's data are required before the increasing trend in cat numbers can be confirmed.

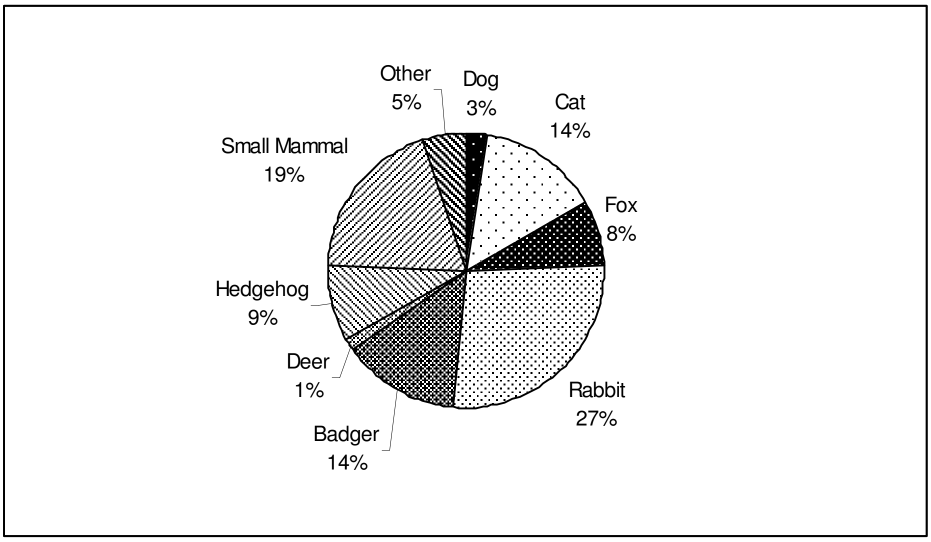


Figure 19: Dead vertebrates, other than bats, observed during all surveys 2006-2008 n=78. Surveys prior to 2006 did not include cats and dogs or records between transects, so results are not included. 'Small mammals' category includes mice and rats. The 'Other' category includes crows (2) and pheasants (1).

Comparing the live (Figure 17) versus dead (Figure 19) specimen pie charts reveals quite a discrepancy in species distribution of the two. Cats only constitute 14% of the dead specimens observed, despite accounting for over 50% of all live vertebrate sightings. Rabbits, the third most frequently recorded living vertebrates, are the most commonly observed dead species found along roadsides, accounting for 27% of all dead specimen records. Also, badgers constitute 14% of the dead animals encountered compared with just 2% of the live fauna. Similarly, just 2% of live specimens are hedgehogs, while this species accounts for 9% of the dead roadside fauna.

Discussion

Volunteer uptake

To date there has been little difficulty recruiting volunteers for the car-based bat monitoring survey. Training has been relatively informal but targeted solely at surveyors who have committed to volunteering the time required. This approach has worked well. Surveyors have shown a very high level of dedication with a relatively low turnover of team leaders from year to year. Certain squares have a higher turnover than others, mainly due to a lack of resident bat workers or wildlife officers with available time in those locations. The high level of year to year repetition among core surveyors is one of the reasons why the survey has been so successful in reaching its targets each year.

Survey coverage

Since 2007 up to 28 squares distributed around the island have been surveyed yearly. This is very good coverage with all regions of the country included in the survey. Bat encounter rates can therefore be assumed to provide a good representation of overall encounter rates for roadsides throughout the island.

Dataset

Good numbers of bats are generally encountered by the survey. In total 13,606 bat encounters have been recorded since the first surveys were carried out in 2003. Over 50% of these are common pipistrelles with soprano pipistrelles and Leisler's bats recorded in similar numbers accounting for 20% each. Comparisons with data from the Bats and Roadside Mammals Project in the UK, for example in 2008, (Russ *et al.*, 2008), show almost universally higher encounter rates among these species in Ireland compared with Britain. Common pipistrelle encounter rates were 1.05km^{-1} in Ireland, compared with 0.81km^{-1} in Britain in 2008. Soprano pipistrelle encounter rates were also higher in Ireland, 0.48km^{-1}, compared with 0.39km^{-1} in Britain in 2008. The encounter rate with Leisler's bat in Ireland was a whole order of magnitude higher at 0.46km^{-1} compared with Britain at 0.01km^{-1}. It should be noted that there are several differences in methodology between the two surveys that may account for differences in species encounter rates between the two islands, although Leisler's bat is most certainly more abundant in Ireland than Britain.

Abundance and Diversity

Examination of both encounter rates and recorded bat diversity in each of the 30km squares shows that, while some of the low encounter rate squares are quite diverse and some high encounter rate squares less so, when the two elements are combined the most abundant squares with high bat diversity are found in the south west, midlands and east of the country. V96 and V93, in Kerry and west Cork, respectively, along with S78 in Carlow/west Wicklow are the survey squares with greatest abundance and bat diversity combined. While habitat analysis may contribute to some understanding of this result, particularly with regard to the specific squares highlighted, climate is also likely to play a significant role in these findings. Ideally, it should be possible to develop a predictive model for general bat activity and diversity along roadsides throughout the island, based on the current dataset and an analysis of habitats and climate.

Species Abundance and Yearly Trends

Common Pipistrelles

This species is distributed widely throughout the country but it has never been recorded during the surveys of L64 in Connemara. This species is significantly correlated with grid reference eastings and negatively correlated with northings (Roche *et al.*, 2007). It is less frequently encountered in the extreme north and north-west although it does occur there.

Highest common pipistrelle encounter rates were recorded by the car-based bat monitoring scheme in 2007. Encounter rates dropped slightly in 2008. July and August 2008 were exceptionally wet and high rainfall may have accounted for the slightly depressed activity of this species compared with the previous year (weather data from www.meteireann.ie). Despite the slight drop in activity levels from 2007 to 2008 this species may, overall, be on an increasing trend, although this needs to be verified with more years of data. Certainly, for an opportunistic forager such as the common pipstrelle (e.g. Davidson-Watts *et al.*, 2006), increasing air temperatures associated with continuing climate change seem likely to result in population increases (see also Roche *et al.*, 2008 for more detailed discussion).

Soprano pipistrelles

Soprano pipistrelles are usually the second most frequently encountered species by the car-based bat monitoring scheme (2006 excepted). This species may not occur along roads as frequently as the common pipistrelle, or, because it has higher frequency echolocation calls, it may not be as detectable where it does occur.

A gradation in activity distribution of this species is not as apparent for this species as it is for the common pipistrelle. Highest encounter rate survey squares mainly, however, occur in the west of the island and lowest encounter rate squares are located in the east and extreme north. In some studies soprano pipistrelles have been shown to actively select riparian habitats for foraging (e.g. Davidson-Watts *et al.*, 2006; Nicholls and Racey, 2006; Russ and Montgomery 2002). The west of Ireland, with its high rainfall and relatively mild temperatures may therefore provide ideal conditions for this species, while the extreme north may be less ideal due to lower average temperatures.

Soprano pipistrelles were recorded more frequently in 2008 than in any previous year, despite the high rainfall experienced during the two survey months in that year. The soprano pipistrelle population may be increasing but more years of data need to be collected before any conclusions can be made. The Bats and Roadside Mammals project in Britain saw a parallel increase in soprano pipistrelle encounters in 2008 (Russ *et al.*, 2008).

Leisler's Bat

This species is usually the third most frequently encountered species from the monitoring scheme (excepting 2006 when it was second, see Roche *et al.*, 2007). The encounter rate with Leisler's bats increased in 2008 compared with 2007.

In 2006, REML analysis showed a significant positive association with the south of the island, and an association of borderline significance with the east of the island. Average encounter rate data from 2004 to 2008 confirms these associations, whereby squares with high Leisler's activity are concentrated in the south and east of the island.

The population of this species may be on an increasing trend, although, at the relatively early stage of year six of the scheme, this needs to be verified with more years of surveying. Comparable data from the 'Bats and Roadside Mammals' project in Britain showed a decrease in Leisler's abundance in 2008 compared with 2007 (Russ *et al.*, 2008) but overall trend data is not yet available from Britain since the project has been running there for a shorter timescale.

Nathusius' Pipistrelle

This species was recorded for the first time by the car-based bat monitoring scheme in a square in the north-east in 2005. 2006 saw a massive increase in the number of Nathusius' pipistrelle encounters along with an increase in the number of squares where the species was recorded. While 2006 was the first year that included surveys in Northern Ireland, many of the new records for the species were derived from squares south of the border and where the species had not been previously recorded. The bat was recorded in additional squares in 2007, but was not re-recorded in all of the squares where it had been observed in 2006. In 2008 the encounter rate with this species dropped further so that it now appears as though the population is on a quadratic trend. Encounters with the species are so low, however, that large error bars surround the trend estimates and any discussion on patterns in the data should be viewed with caution. The records of Nathusius' pipistrelle derived from the car-based bat monitoring scheme are widely distributed across the island but so far the species has been absent from survey squares in the mid-west.

A similar increase in Nathusius' pipistrelle abundance to that observed in Ireland in 2006 was recorded by the car-based bat survey in the UK in 2006 (Russ *et al.* 2006) and the encounter rate with this species has continued to drop from the 2006 levels in Britain (see Russ *et al.*, 2007 and Russ *et al.*, 2008).

Myotis Bats

Small numbers of *Myotis* bats have been encountered each year. No *Myotis* calls were identified to species level. Numbers of encounters with *Myotis* species from the car-based bat monitoring scheme are too low to determine population trends. *Myotis* bats have been recorded in most survey squares.

Brown Long-eared Bat

Social calls from this species were recorded by the car-based bat monitoring scheme for the first time in 2005. Similar numbers of encounters with the species were recorded in 2006 and 2007. The number of encounters is still too low to determine population trends, however. This species has been recorded from more than half of the survey squares and records have been widely distributed around the island.

Power Analysis

Power analysis was revisited using all the data available from 2003. Results confirmed that car-based bat monitoring is a robust method for monitoring the three target species – common pipistrelle, soprano pipistrelle and Leisler's bat.

With between 20 and 25 squares surveyed twice yearly the number of years required to achieve 80% power for Red Alert declines is approximately 7-8 for common pipistrelles and 10-12 for soprano pipistrelles and Leisler's bats. Amber Alerts take longer to achieve at 14-16 years for common pipistrelles and 19-22 for soprano pipistrelles and Leisler's bats.

It has been assumed, to date, that the time needed to achieve 80% power to detect Red or Amber Alert decreases would mirror the time needed to achieve 80% power for equivalent increases. This assumption was checked for the first time and was shown to be roughly correct. Some differences were visible in the time needed to achieve 80% power with lower number of squares (10) but these particular results may not be reliable since this number of squares is too low for the bootstrapping process anyway. In reality a far higher number of squares, between 22 and 24, are surveyed twice yearly.

The real data collected by the car-based bat monitoring scheme should therefore be on target to achieve power for declines or increases within the timeframes shown.

Reducing Survey Time

Roche *et al*. (2008) reviewed the options available for reducing survey time. Statistically, there were some concerns about removing the two mile gap between transects and driving a continuous route, even though this would make the Irish scheme comparable to some of the other European monitoring schemes. Therefore, analyses were carried out to determine the affect on power of reducing the number of transects on a survey route. At the current number of squares surveyed (between 20 and

25) with a reduction to 15 transects there is a broad pattern showing a slight increase (approximately 0.5) in the number of years required to achieve 80% power for declines in common pipistrelles and Leisler's bats. The soprano pipistrelle shows a greater increase in timespan by about 2-3 years.

Reducing transect numbers would lessen survey time, lower fuel costs and reduce the carbon footprint of the scheme. If the increase in time required to detect declines (by roughly half a year for common pipistrelles and Leisler's and two to three years for soprano pipistrelles) is considered acceptable, then reducing survey length to 15 transects appears ideal. With this number of transects per survey it would not be necessary to increase the number of squares to compensate for loss in precision. Average length of survey time for a 15 transect survey would be reduced by one hour. Therefore the surveyor input per annum could be expected to decrease to roughly 300hrs (based on two person teams).

Other Vertebrates

Average encounter rates with other vertebrates have increased yearly since 2006. However, this increase is due to a corresponding increase in cat numbers. The cat is by far the most commonly occurring mammal species along Irish roadsides at night. Cats account for over 50% of all 'other vertebrate' sightings recorded during the car survey. Trends in total vertebrate encounters, excepting cats, have been largely static since 2006 but when more years of data have been collected it may be valid to examine trends in some of the other relatively common species such as foxes and rabbits.

A wider variety of mammal species are present in Britain, as may be expected, but rabbits are the most frequently recorded species there (Russ *et al.*, 2008). Cats are the second most frequently recorded species in Britain where 0.012km^{-1} were recorded in 2008, compared with 0.05km^{-1} in Ireland.

Dead vertebrates along roads are also recorded by the car-based bat monitoring surveyors. Despite their prevalence along Irish roadsides at night, cats are rarely recorded dead on the roads. Just 14% of dead specimens were cats compared with over 50% of live animals. Badgers, rabbits and hedgehogs account for a far greater proportion of the dead fauna observed along roadsides, compared with live fauna. Badger carcasses may persist for longer on the roadside, compared with some small animal carcasses, and hedgehogs may also remain identifiable for a long time on account of their spines. Certain behavioural patterns may account for an increased likelihood of car collisions among these species.

Proposals for the Future of Car-based Bat Monitoring

Methodology

Continue as at present surveying each square twice yearly, but drop the last five transects on each survey route.

Habitat Use

Land classifications for Ireland and possible methods of examining habitat associations of different bat species should be examined in 2009.

REFERENCES

Armitage, P. and Berry, G. (1987) *Statistical Methods in Medical Research*. 2nd Ed. Blackwell Scientific Publications Oxford.

Aughney, T., Carden, R., Roche, N. and Langton, S. (2009) *Irish Bat Monitoring and Recording Schemes: Annual Report for 2008*. *In prep*.

Aughney, T., Langton, S. and Roche, N. (2007) *All-Ireland Daubenton's Bat Waterway Survey 2006, Irish Bat Monitoring Programme.* Bat Conservation Ireland. Report submitted to The National Parks and Wildlife Service.

Aughney, T. and Roche, N. (2008) *Brown long-eared bat* Plecotus auritus *Roost Monitoring 2007, Irish Bat Monitoring Programme*. Bat Conservation Ireland. Report submitted to The National Parks and Wildlife Service.

Aughney, T. and Roche, N. (2009) *Brown long-eared bat* Plecotus auritus *Roost Monitoring 2008, Irish Bat Monitoring Programme*. Bat Conservation Ireland. Report submitted to The National Parks and Wildlife Service.

The Bat Conservation Trust (2006). The National Bat Monitoring Programme: Annual Report 2005. BCT, London.

Baillie, S.R., Crick, H.Q.P., Balmer, D.E., Beaven, L.P., Downie, I.S., Freeman, S.N., Leech, D.I., Marchant, J.H., Noble, D.G., Raven, M.J., Simpkin, A.P., Thewlis, R.M. & Wernham, C.V. (2002) *Breeding Birds in the Wider Countryside: their conservation status 2001*. Research Report 278. BTO, Thetford.

Buckland S.T., Magurran A.E., Green R.E. and Fewster R.M. (2005) Monitoring change in biodiversity through composite indices. *Philos. T. Roy. Soc. B.* **360**: 243-254.

Catto, C., Russ, J. and Langton, S. (2004) *Development of a Car Survey Monitoring Protocol for the Republic of Ireland*. Prepared on behalf of the Heritage Council by the Bat Conservation Trust UK. The Heritage Council, Ireland.

Fairley, J. (2001) *A Basket of Weasels*. Northern Ireland.

Fewster, 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.

Hutson, A.M., Mickleburgh, S.P. and Racey, P.A. (2000) *Microchiropteran bats: global status survey and conservation action plan.* IUCN/SSC Chiroptera Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK.

Lewis, T. and Stephenson, J.W. (1966) The permeability of artificial windbreaks and the distribution of flying insects in the leeward sheltered zone. *Annals of Applied Biology*, **58**: 355-363.

Limpens, H.J.G.A. and Kapteyn, K. (1991) Bats, their behaviour and linear landscape elements. *Myotis*, **29**: 39-48.

Marchant, J.H., Wilson A.M., Chamberlain D.E., Gregory R.D. and Baillie S.R. (1997) *Opportunistic Bird Species – Enhancements for the Monitoring of Populations*. BTO Research Report No. 176. BTO, Thetford.

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

Nicholls, B. and Racey, P.A. (2006) Contrasting home-range size amd s[atial partitioning in cryptic and sympatric pipistrelle bats. *Behavioural Ecology and Sociobiology*, **61**: 131-142.

NPWS (2007) *The status of EU protected habitats and species in Ireland*. National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government. Dublin, Ireland.

Roche, N. and Aughney, T. (2007) *Pilot Scheme for Monitoring Woodland Bats in the Republic of Ireland*. Bat Conservation Ireland. Report submitted to The National Parks and Wildlife Service.

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 the Environment, Heritage and Local Government, Dublin.

Roche, N., Langton, S., Aughney, T. and Haysom, K. (2006) *The Car Based Bat Monitoring Scheme for Ireland: Report for 2005*. Bat Conservation Ireland.

Roche, N., Langton, S., Aughney, T. and Russ, J. (2007) *The Car Based Bat Monitoring Scheme for Ireland: Report for 2006*. Bat Conservation Ireland.

Roche, N., Langton, S. and Aughney, T. (2008) *The Car Based Bat Monitoring Scheme for Ireland: Report for 2007.* Bat Conservation Ireland.

Russ, J., Briggs, P. and Wembridge, D. (2007) *The Bats and Roadside Mammals Project. Final Report on the Third Year of Study*. The Bat Conservation Trust and the Mammals Trust UK.

Russ, J., Briggs, P. and Wembridge, D. (2008) *The Bats and Roadside Mammals Project. Final Report on the Fourth Year of Study*. The Bat Conservation Trust and the Mammals Trust UK.

Russ, J., Catto, C. and Wembridge, D. (2006) *The Bats and Roadside Mammals Project. Final Report on the Second Year of Study*. The Bat Conservation Trust and the Mammals Trust UK. The Bat Conservation Trust UK and The Mammal Society.

Russ, J.M. and Montgomery, W.I. (2002) Habitat associations of bats in Northern Ireland: implications for conservation. *Biological Conservation* **108**: 49-58.

Rydell, J. (1992) Exploitation of insects around streetlamps by bats in Sweden. *Functional Ecology* **6**: 744-750.

Sims, M, Elston, D.A., Harris, M.P. and Wanless, S. (2006) Incorporating Variance Uncertainty into a Power Analysis of Monitoring Designs. *Journal of Agricultural, Biological, and Environmental Statistics* **12**: 236–249.

Stebbings, R.E. (1988) *Conservation of European Bats*. Christopher Helm, London.

Taylor, L.R. (1963) Analysis of the effects of temperature on insects in flight. *Journal of Animal Ecology* **32:** 99-117.

Temple, H.J. and Terry, A. (2007) *The Status and Distribution of European Mammals*. Office for Official Publications of the European Communities, Luxembourg.

Verboom, B. and Spoelstra, K. (1999) Effects of food abundance and wind on the use of tree lines by an insectivorous bat, *Pipistrellus pipistrellus*. *Canadian Journal of Zoology* **77**: 1393-1401.

Wellington, W.G. (1945) Conditions governing the distribution of insects in the free atmosphere. *The Canadian Entomologist* **77**: 7-15.

Whilde, A. (1993) *Irish Red Data Book 2: Vertebrates*. HMSO, Belfast.

Williams, C.B. (1940) An analysis of four years captures of insects in a light trap: Part II. The effects of weather conditions on insect activity; and the estimation and forecasting of changes in the insect population. *Transactions of the Royal Entomological Society of London* **90:** 227-306.

Glossary of Terms

Bootstrapping

This is a method for estimating the sampling distribution of an estimator by resampling with replacement from the original sample. In the context of population indices the resampling is done for entire sites and ensures that confidence limits and significance levels are unaffected by any temporal correlation in the data. It also allows for the effects of 'overdispersion' which occurs when data are more variable than expected from a Poisson distribution.

Covariate

This is a variable that is possibly predictive of the outcome under study. A covariate may be of direct interest or be a confounding variable or effect modifier.

Doppler Effect

Apparent change in frequency of a sound (measured in kilohertz, kHz) as a result of movement, either of the source or the observer. The apparent frequency of a sound increases as the source of the sound moves towards an observer or the observer move towards it and decreases as the source moves away from an observer or the observer moves away from it.

GLM

Generalised Linear Model: a generalisation of ordinary regression and analysis of variance models, allowing a variety of different error distributions and different link functions between the response variable and the explanatory variables. The models used here have a Poisson error distribution and a logarithmic link.

GAM

Generalised additive model: these models allow a smooth, non-parametric curve to be fitted to an explanatory variable, within a GLM. In estimating population indices they are used to smooth out year-to-year variation (Fewster *et al*. 2000).

Offset

A covariate with a fixed slope of 1.0, in this case implying that the total count doubles if the number of recording intervals doubles.

Poisson Distribution

The Poisson distribution is a discrete probability distribution. It expresses the probability of a number of events occurring in a fixed time if these events occur with a known average rate, and are independent of the time since the last event. It is frequently used as the basis of statistical models of counts of organisms or events.

Power Analysis

Analysis of the power (probability) to reject a false null hypothesis. A test with high power has a large chance of rejecting the null hypothesis when this hypothesis is false. In the case of the present project the null hypothesis would state that that there is no decline in bat populations. Power is measured as a percentage, and greater power reflects the increased likelihood of detecting a declining trend (as outlined for Red or Amber Alerts). The power analysis carried out for the present project is one-tailed (i.e. examines a declining trend only) at P=0.05 (which is equivalent to P=0.1 for a two sided test).

REML

Restricted (or residual) maximum likelihood (REML) is a method for fitting linear mixed models. In contrast to conventional maximum likelihood estimation, REML can produce unbiased estimates of variance and covariance parameters. This method assumes the data are normally distributed.

Relative Standard Error

The standard error of an estimate expressed as a proportion of the percentage of the estimate. Also known as the coefficient of variation.

APPENDIX I

Methods

Training and equipment

Training workshops to explain the project to new surveyors and demonstrate the equipment were carried out in June and July 2008 in Belfast and Longford.

During training workshops volunteers/NPWS/EHS staff are presented with an information pack which includes an outline of the protocol for the car survey, a distribution map showing twenty randomly generated 30km² 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 and Northern Ireland, guidelines for using the minidisc recorder, and two recording sheets, one to record transect details and one to record survey information. In addition, each surveyor is equipped with maps, a minidisc recorder, a stereo connecting lead, a bat detector (Tranquillity Transect), a car window mounting clamp, a thermometer, a first aid kit and a flashing beacon. A training CD is also provided. This demonstrates sounds that surveyors should be able to hear while surveying, sounds that indicate problems with equipment, bat sounds and other sounds that surveyors may encounter during the survey.

The car transect method is employed to monitor bat activity within twenty 1.609 km (1 mile) monitoring transects along a selected survey route within randomly generated 30km² squares. Time expansion bat detectors are used to assess bat activity along the route and bat calls are recorded onto a minidisc recorder.

Each surveyor is assigned at least one 30 km² 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 are recorded by the surveyor on the appropriate form and highlighted on the maps provided.

Each survey square is driven in July. A repeat survey is carried out in mid-August 2007. The bat detector is 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 begins 45 minutes after sunset and volunteers are 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 is transferred to a computer hard drive as separate *.wav files representing the numbered tracks (20 files, one for each monitoring transect) on the minidisc using the software Win Nmd (v1.2x, Christian Klukas). Occasionally, multiple tracks are recorded for each monitoring transect and these are joined into a single *.wav file using the software program AddAWav (v1.5, Geoff Phillips). Using Bat Sound (Pettersson Elektronik AB) software, bats are categorised into species from the measured parameters of their echolocation calls.

Each adjacent 320ms time expanded sequence is treated as an independent sample, and therefore species occupying adjacent 320ms sequences are treated as separate individuals. It is occasionally possible to identify more than one individual of the same or different species within a single 320 ms sequence.

The REML models are fitted using the average number of passes per minute for each 1.6km long monitoring transect. The small number of instances where the monitoring transect contains less than 50 0.32 second recording periods are excluded, as the models suggest that these produce abnormally low counts. No attempt has been made to fit models to the *Myotis* spp. data (or to the indeterminate pipistrelles) as there is far too little data to permit sensible modelling.

Power Analysis

Simulations are based on the variance components from a REML model of suitably transformed bat counts per survey, 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 produced the required long-term trend. Uncertainty in the estimates of variances can lead to erroneous estimates of power (Sims *et al.*, 2006) and so each simulated dataset is based on variance estimates taken from a bootstrapped version of the original dataset, thus ensuring that the power results are effectively averaged over a range of plausible values of the variance estimates.

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

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

Last year a log-normal transformation of the counts was initially used, but this tended to produce a small number of implausibly large numbers of bat passes. The results presented here therefore use a transformation based on normal scores (see for example Armitage and Berry, 1987) which was more successful in mimicking the distribution of the real data.

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 the decline 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.

APPENDIX II

Results

Simpson's Index

Table A1: Simpson Index of Diversity and Overall Average Bat Abundance for all surveys. Red highlights abundance >60 and diversity (1-D) ≥0.6; Yellow highlights abundance >55 and diversity (1-D) ≥0.5.

Square	Simpsons Index (D)	Simpson's Index of Diversity (1-D)	Total encounters/hr
C72	0.30	0.70	15.77
G20	0.34	0.66	21.05
G53	0.44	0.56	20.58
G89	0.30	0.70	24.20
H13	0.40	0.60	34.60
H40	0.39	0.61	38.64
H79	0.50	0.50	29.44
J06	0.33	0.67	43.98
J33	0.44	0.56	28.46
L64	0.54	0.46	10.33
M24	0.35	0.65	35.90
M87	0.31	0.69	23.73
N11	0.48	0.52	58.34
N74	0.54	0.46	63.34
N77	0.41	0.59	68.65
O04	0.57	0.43	41.03
R22	0.46	0.54	78.87
R28	0.32	0.68	39.21
R88	0.47	0.53	50.29
S12	0.42	0.58	64.62
S15	0.46	0.54	50.28
S78	0.39	0.61	63.48
T05	0.46	0.54	47.59
V93	0.35	0.65	63.70

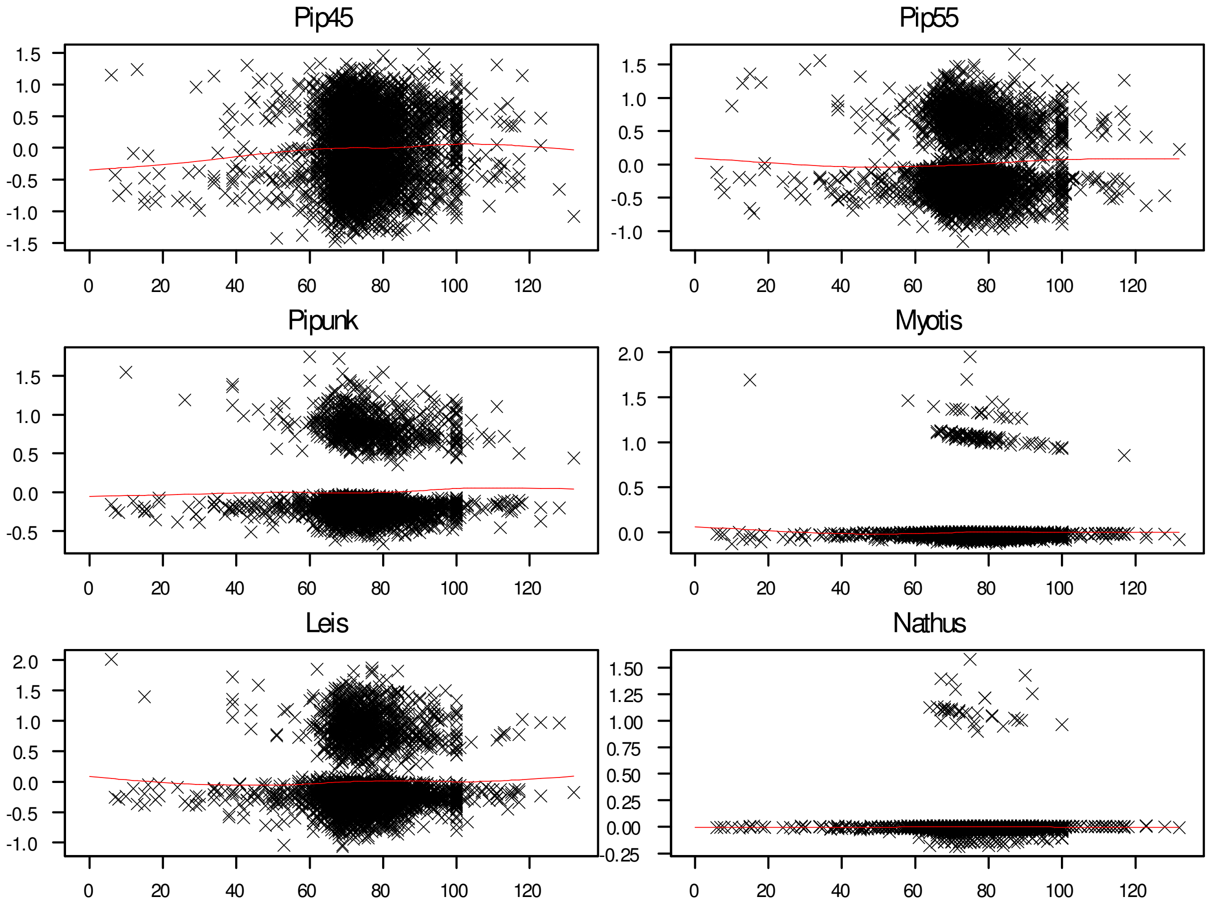
V96	0.36	0.64	70.94
V99	0.50	0.50	81.28
W56	0.49	0.51	66.85
X49	0.34	0.66	30.60

Relationship with Number of Intervals

The Tranquility Transect detectors are set to record continuously for 320 milliseconds and they then play back this ultrasound more slowly (x10) so that, when analysis is carried out, recordings are visible as 3200ms of slowed-down sounds with short gaps in between each when the detector is recording. Each piece of slowed-down sound is referred to as an interval or snapshot and a single bat echolocation call or sequence of echolocation calls in one snapshot is referred to as a bat encounter. Typically, recordings from a single transect consist of 70-75 snapshots.

In previous years, transects with less than 50 320ms recording snapshots have been excluded as these seemed to produce some atypical values. Since this assumption had not been checked for a number of years, some models were fitted to investigate the relationship between passes and number of snapshots. A REML model was fitted to the log-transformed number of passes per minute using the data for all one mile transects, and then the residuals from each one mile transect were plotted against the number of 320ms snapshots or intervals. If the number of passes per minute is independent of the number of snapshots, as it should be, there should be no relationship between the two (i.e. a mess of points). Figure 1 shows the results; to make it easier to spot any trend, a smoothed fitted line is shown, which should be horizontal if there is no relationship.

Figure 1; residuals from a REML analysis plotted against number of 0.32ms snapshots. The red line is a fitted line (spline with 4d.f.).



As can be seen, the lines are more or less horizontal, but do show some signs of an upward slope for low numbers of snapshots for common pipistrelles, and a downward slope for soprano pipistrelles, *Myotis* spp. and Leisler's. These slopes level off at different points for different species; for common pipistrelles it is around 50-60 snapshots, but for other species it is less. It is also worth noting that, for all species, the effects are fairly subtle. We did, therefore, consider changing the 50 snapshots criterion for a lower value, but in practice the gain in data is very small, with only one more survey producing enough data to contribute to the GLM models. Therefore, the 50 snapshots criterion has been retained.

Descriptive Statistics

The tables below show some simple descriptive statistics for each year. Transects with less than 50 0.32ms recordings have been excluded as these may produce some atypical values.

Table A2: Descriptive statistics

a) Common pipistrelles

		Statistics per mile transect			**Statistics per 0.32ms recording**			
year	**Total passes**	**n transects**	**mean passes**	**% with passes**	**n**	**n with**	**% with passes**	**passes per min**
2003	217	173	1.25	50.3	13225	217	1.64	3.00
2004	1055	545	1.94	57.4	41542	1023	2.46	4.80
2005	811	596	1.36	52.2	47170	798	1.69	3.23
2006	1506	880	1.71	52.7	67314	1443	2.14	4.24
2007	1567	880	1.78	53.9	65312	1489	2.28	4.49
2008	1551	900	1.72	48.1	66603	1551	2.33	4.32
All years	6707	3974	1.69	52.4	301166	6521	2.17	4.19

b) Soprano pipistrelles

		Statistics per mile transect			**Statistics per 0.32ms recording**			
year	**Total passes**	**n transects**	**mean passes**	**% with passes**	**n**	**n with**	**% with passes**	**passes per min**
2003	82	173	0.47	24.9	13225	82	0.62	1.15
2004	386	545	0.71	34.3	41542	377	0.91	1.71
2005	333	596	0.56	31.5	47170	329	0.70	1.32
2006	573	880	0.65	33.4	67314	562	0.83	1.55
2007	566	880	0.64	32.2	65312	550	0.84	1.62
2008	702	900	0.78	37.1	66603	702	1.05	1.94
All years	2642	3974	0.66	33.4	301166	2602	0.86	1.62

c) 50khz pipistrelles (NB shown as missing in dataset for 2003)

		Statistics per mile transect			**Statistics per 0.32ms recording**			
year	**Total passes**	**n transects**	**mean passes**	**% with passes**	**n**	**n with**	**% with passes**	**passes per min**

2003								
2004	247	545	0.45	29.2	41542	247	0.59	1.12
2005	159	596	0.27	20.0	47170	159	0.34	0.63
2006	239	880	0.27	18.6	67314	238	0.35	0.67
2007	225	880	0.26	17.7	65312	221	0.34	0.65
2008	266	900	0.30	17.6	66603	266	0.40	0.74
All years	1136	3801	0.30	19.9	287941	1131	0.39	0.74

d) Myotis spp.

		Statistics per mile transect			**Statistics per 0.32ms recording**			
year	**Total passes**	**n transects**	**mean passes**	**% with passes**	**n**	**n with**	**% with passes**	**passes per min**
2003	7	173	0.04	2.9	13225	7	0.05	0.11
2004	28	545	0.05	4.4	41542	28	0.07	0.12
2005	21	596	0.04	2.3	47170	21	0.04	0.08
2006	26	880	0.03	2.4	67314	26	0.04	0.07
2007	32	880	0.04	2.5	65312	32	0.05	0.09
2008	26	900	0.03	2.4	66603	26	0.04	0.07
All years	140	3974	0.04	2.7	301166	140	0.05	0.09

e) Leisler's

		Statistics per mile transect			**Statistics per 0.32ms recording**			
year	**Total passes**	**n transects**	**mean passes**	**% with passes**	**n**	**n with**	**% with passes**	**passes per min**
2003	52	173	0.30	15.6	13225	52	0.39	0.72
2004	295	565	0.52	23.2	43087	293	0.68	1.31
2005	314	596	0.53	21.6	47170	314	0.67	1.24
2006	787	880	0.89	27.6	67314	769	1.14	2.26
2007	557	880	0.63	20.3	65312	547	0.84	1.56
2008	672	900	0.75	24.2	66603	672	1.01	1.90
All years	2677	3994	0.67	23.2	302711	2647	0.87	1.67

f) Nathusius' pipistrelle

		Statistics per mile transect			**Statistics per 0.32ms recording**			
year	**Total passes**	**n transects**	**mean passes**	**% with passes**	**n**	**n with**	**% with passes**	**passes per min**
2003	0	173	0.00	0.0	13225	0	0.00	0.00
2004	0	565	0.00	0.0	43087	0	0.00	0.00
2005	1	596	0.00	0.2	47170	1	0.00	0.00
2006	29	880	0.03	2.2	67314	28	0.04	0.08
2007	13	880	0.01	1.2	65312	13	0.02	0.04
2008	6	900	0.01	0.7	66603	6	0.01	0.02
All years	49	3994	0.01	0.9	302711	48	0.02	0.03

g) Brown long-eared (not separately recorded before 2007)

		Statistics per mile transect			**Statistics per 0.32ms recording**			
year	**Total passes**	**n transects**	**mean passes**	**% with passes**	**n**	**n with**	**% with passes**	**passes per min**
2003								
2004								
2005								
2006								
2007	17	880	0.02	1.4	65312	17	0.03	0.05
2008	2	900	0.00	0.2	66603	2	0.00	0.01
All years	19	1780	0.01	0.8	131915	19	0.01	0.03