THE CAR-BASED BAT MONITORING SCHEME FOR IRELAND: REPORT FOR 2006

Niamh Roche[1], Steve Langton[2], Tina Aughney[1], Jon Russ[3]

1. www.batconservationireland.org
2. stats@slangton.co.uk
3. www.bats.org.uk

CONTENTS

EXECUTIVE SUMMARY

Introduction

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 (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) and The Heritage Council. In 2006 it was extended to Northern Ireland with additional funding from the Environment and Heritage Service (EHS), 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 act as an early warning system for Amber or Red Alert declines in these 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 has been increasing yearly and in 2006, routes had been mapped in 26, 30km blocks. Surveys are carried out in July and August by trained volunteers who are mainly staff of NPWS and EHS and BCIreland members. Fifty nine surveyors were involved in surveying in 2006, the maximum number involved to-date.

An experimental field trial was carried out in September 2005 and June 2006 to determine the impacts of driving speed on bat observability. The results of this experiment indicate that more bats are observed at slower speeds in areas where bat activity is high, but the relationship between numbers of bats observed and driving speed are less predictable where bat activity levels are generally low. By displaying results in the present report as number of bat encounters per unit time rather than per unit distance the effects of speed on bat observability can be largely accounted for, however. In addition, for detailed statistical analysis, e.g. Generalised Linear Models, time is included as a covariate in the models.

Twenty six survey squares were mapped and surveyed by the end of 2006. During the July and August 2006 surveys, 3211 bat encounters were recorded from 887 independent monitoring transects. The common pipistrelle was the most frequently encountered species, as in previous survey years. On average 1.7 common pipistrelle encounters were recorded during each 1.6km transect. The soprano pipistrelle, which was the second most frequently encountered species in all years to 2005, was the third most frequently encountered species. On average 0.65 soprano pipistrelle encounters were recorded from each 1.6km transect. The Leisler's bat was the second most frequently encountered bat in

2006, whereas in prior years it was the third most frequent species. On average, 0.89 Leisler's bats were encountered during each 1.6km transect in 2006. Abundance of all species excluding *Myotis* spp. was higher in 2006 than in 2005.

Data on population trends have not yet shown any discernible patterns for the common or soprano pipistrelles, both populations of which show large year to year variation. The Leisler's bat population appears, however, to be increasing. The Nathusius pipistrelle, one of the most recent additions to Ireland's mammalian fauna and which was only recorded once by the present scheme in all years to 2005, showed a dramatic increase in abundance and distribution in 2006.

From a REML model common pipistrelles show a significant correlation with grid reference eastings and are negatively correlated with northings, i.e. abundance of this species is greatest in the south east of the country. The soprano pipistrelle is most abundant in the west, although the negative correlation with eastings is not significant. The Leisler's bat is most frequent in the eastern half of the country.

Power Analysis, the statistical method that determines the percentage certainty for correctly identifying declines, was not carried out in 2006. Arising from initial examination of air temperature data and bat activity some of the potential impacts of climate change on the Irish bat fauna are discussed.

Other vertebrates were recorded by surveyors throughout each survey evening and in total 322 living vertebrates other than bats were recorded from 4199km of roads in July and August 2006. The most common species was the cat which accounted for 50% of all living vertebrates observed. The next most common were dogs and rabbits. Rabbits were the most commonly recorded dead vertebrates.

INTRODUCTION

The Car-Based Bat Monitoring Project is a joint scheme of The National Parks and Wildlife Service (NPWS) of The Department of Environment, Heritage and Local Government, The Heritage Council and Bat Conservation Ireland (BCIreland) with input from The Bat Conservation Trust (BCT). This project aims to be the main 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 in 2003 as an initiative of The Heritage Council (Catto *et al*., 2004).

This report presents results for the 4th season of bat monitoring in the Republic of Ireland and follows earlier reports (Catto *et al.,* 2004; Roche *et al*., 2005, Roche *et al*., 2006). The format follows Roche *et al*. (2005) although revised methods of analysis and increased data availability means that there have been some changes to the annual report format for 2006.

2005 saw the first survey square to be completed in Northern Ireland. In 2006 the Environment and Heritage Service (EHS), Department of the Environment, Northern Ireland, funded the monitoring of three squares in Northern Ireland, the results from which are included in the overall dataset 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.

Ireland and the UK are also signatory to a number of conservation agreements pertaining to bats such as the Bern and Bonn Conventions. The European Bats Agreement (EUROBATS) is an agreement under the Bonn Convention and Ireland and the UK are two of the 31 signatories. The Agreement has an Action Plan with priorities for implementation. Devising strategies for monitoring of populations of selected bat species in Europe is among the resolutions of EUROBATS.

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

There has been an increase in levels of knowledge of Irish bats in the past 20 years, mainly due to increased numbers of researchers and bat workers. Despite high levels of legal protection for all species, however, until 2003 there was no systematic monitoring of any species apart from the lesser horseshoe bat. This car-based bat monitoring scheme, the Daubenton's Bat / Waterways Survey which began in 2006 and the pilot of woodland bat and long-eared bat monitoring schemes are helping to redress the imbalance, ensure countrywide coverage and monitoring of a number of species including the IUCN listed 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 subsample 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

There are no precise biological definitions of when a population becomes vulnerable to extinction but the British Trust for Ornithology (BTO) has produced Alert levels based on IUCN-developed criteria for measured population declines. Species are considered of high conservation priority (Red Alert) if their population has declined by 50% or greater over 25 years and of medium conservation priority (Amber Alert) if their populations have declined by 25-49% over 25 years (Marchant *et al*., 1997). These Alerts are based on evidence of declines that have already occurred but if Alerts are *predicted* to occur based on existing rates of decline in a shorter time period then the species should be given the relevant Alert status e.g. if a species has declined 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 included detailed analyses of the sensitivity achieved by the car-based approach and power analysis to evaluate alternative approaches for the future. Power analysis, which was carried out on each year's data from 2003 to 2005, was not carried out in 2006.

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 lining 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 help allow informed decisions on future road network developments leading to lessened environmental impacts. Data collected from this monitoring scheme also have potential applications on a national and regional basis.

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

CAR-BASED BAT MONITORING

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

Future Aims

- To correlate information on bat activity with habitat availability to determine important habitats for foraging bats in Ireland.
- To determine population trends and allow early detection of population declines.

2006 BAT MONITORING SCHEME

The Aims of this Report
This fourth annual report is an essential tool to disseminate the results to volunteers who diligently mapped survey routes and carried out survey work for many hours at night time. In addition, the yearly report aims to provide a reference source for policy and decision makers. This fourth yearly report compares the data available for the four years surveyed to-date.

For some species, trends in populations are already becoming apparent. For others, large yearly fluctuations make this task more difficult. However, yearly activity levels are presented and graphical comparisons can be made. This report illustrates results from different squares around the country and examines activity distributions of the different species. The ratio of common pipistrelle activity to soprano pipistrelle activity was examined for the first time in 2004 (Roche *et al*. 2005). This has been revisited in the present report and some analyses of geographical trends for each species have been carried out using REML statistics.

Identification of Sites of Importance
Other than the Annex II listed lesser horseshoe bat for which large roosts are designated Special Areas of Conservation, there are no guidelines or criteria that can be used as a reference to indicate whether bat activity levels are particularly high (or low). This report highlights survey squares where consistently high bat activity has been recorded, based on mean encounter rates for 2004 to 2006. As data collection continues, criteria defining sites of importance are likely to become better established.

Interpretation of Bat Encounter Data
Following the discovery of echolocation in the 1950's and the subsequent development of bat detectors, there has been a vastly increased level of investigation of bat species worldwide. Bat detectors are a non-invasive method of establishing presence or absence of bats in a certain area and depending on detector type and /or observer skill, can allow identification of the species present (Elliott 1999). 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 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. See below for details.

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 potential effects of variations in driving speed have been examined using a field experiment. See below for details.
- ***Irish Bats and Climate Change*** - at many climatological stations around the country, 2006 was the warmest year since 1997. The mean annual air temperature at Dublin (Phoenix Park) was the highest recorded since records began in 1855. June, July, September and October were particularly warm months throughout the country and March was the only month in 2006 where mean temperatures dropped below the 30 year average. 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. Generalist foragers, such as common pipistrelles, that are not confined to specific habitats 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 and increased storm events and/or windspeeds.

Weather in July-August 2006

July and August are generally the warmest two months of the year in Ireland, with average air temperature for the entire country in the region of 15°C. The July 30 year (1961-1990) average air temperature for different weather stations around the country varied from 13.8˚C to 15.1˚C depending on location. August 30 year means varied from 14˚C to 15.5˚C. Thirty year mean rainfall in July for different weather stations around the country varied from 46.9mm to 73.3mm. Thirty year mean rainfall in August varied from 70.7mm to 111.2mm depending on location. All weather data derived from www.meteireann.ie.

Driving Speed

From data generated from 2003 to 2005 it was observed that driving speeds in different survey squares were subject to variation. The ability to drive at exactly 24km/hr (i.e. 15mph) may be hampered by

- road conditions
- speedometer display visibility
- acceleration capabilities of the car used
- occasional navigational or other difficulties.

When the methodology for this project was initially designed, the prescribed driving speed of 24kmph was based on a compromise between sonogram quality requirements and the optimum number of monitoring transects that could be surveyed per night. Higher car speeds increase the Doppler effect (see Glossary) on recorded calls which may result in mis-identifications (Catto *et al*., 2004). Initial investigations into the effects of driving speed on bat observability were undertaken in 2005. There may be a number of ways in which driving speed can impact bat detectability:

A. At higher speeds some potential bat encounters may not be recorded.
B. The number of encounters may depend on the length of time of recording, not the distance travelled. Thus driving faster may result in a lower number encounters per km because recording time is shorter.
C. Or, the number of encounters might depend on the distance travelled not the time - as would be the case counting fixed objects such as roadside trees. Thus driving faster may have no impact, resulting in the same number of bat encounters recorded.

The magnitudes of B and C will depend on the speed and direction of the bats movement relative to the car. If effect B is dominant, working with calls per unit time may be the best option for displaying results. Alternatively if effect C is dominant, calls per km will be better.

METHODS USED

This car-based bat monitoring method was designed by The BCT 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 2006 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.

Training of surveyors has been carried out in summer prior to Survey 1 each year. In June and July 2006, training of new and existing surveyors by BCIreland was carried out at Belfast, Dublin, Navan, Killarney, Swinford, Lanesborough and Moyne. Training materials were updated and a tailor-made training CD was supplied along with information about street lights. New recording sheets were also provided. In 2006, 26 surveyors, including members of BCIreland, staff of NPWS, staff of The Heritage Council, staff of the EHS and volunteers from Queens University Belfast, along with field work partners, carried out surveys of a mapped route within a defined 30km ***Survey Square***. Five routes were newly mapped in 2006 (J06, H13, H40, N74, V99), the remainder had been mapped in 2003 to 2005. Adjustments were made to a number of existing routes. Every route covered 20 x 1.609km (1 mile) ***Monitoring Transects*** each of which was separated by a minimum distance of 3.2km (2 miles). Surveyors were then asked to carry out the survey on two dates, one in mid to late July (Survey 1, S1) and one in early to mid-August (Survey 2, S2). Each of the 1.609km transects was driven at 24km (15 miles) per hour (at night) while continuously recording from a time expansion bat detector on to minidisc.

Minidiscs were forwarded to BCIreland for analysis.

Each track was downloaded to Bat Sound™ and calls were identified to species level where possible. Species that can be identified accurately using this method are the common, soprano and Nathusius' pipistrelles (*Pipistrellus pipistrellus, P. pygmaeus, P. nathusii*). Leisler's bat (*Nyctalus leisleri*), a low frequency echolocating species, can also be easily identified using this method. Occasional calls of *Myotis* bats were recorded but these are noted as *Myotis* spp. since they could belong to one of a number of similar species – Daubenton's, whiskered, Natterer's or the recently discovered Brandt's bat (*Myotis daubentonii, M. mystacinus, M. nattereri, M. brandtii*). Pipistrelle calls with a peak in echolocation between 48kHz and 52kHz were recorded as 'Pipistrelle unknown' because they could be either common or soprano pipistrelles. Occasional social calls of brown long-eared bats (*Plecotus auritus*) were recorded in 2005 and 2006.

For quality control purposes a number of randomly selected .wav files from 2006 were forwarded to Jon Russ of The BCT for analysis.

Detailed methodology is given in Appendix I.

Driving Speed

A study examining the effects of driving speed on bat observability was carried out by Bat Conservation Ireland in September 2005 at Broad Boyne Bridge, Co. Meath.

Using the same equipment (car window clamp, Tranquility Transect detector set to 320milliseconds, minidisc recorder) two cars were driven repeatedly along a 500m transect. Six speeds were selected – 5 (8), 8 (12.8), 10 (16), 12 (19.3), 15 (24.1), 18 (29) and 20 (32.2) mph (kmph). Two speeds were tested simultaneously (e.g. 5 mph & 8 mph) where Car A was driven at a the faster of the two speeds followed by Car B driven at the slower speed while recording from the bat detector to minidisc. The transect was repeated for each pair of speeds being tested. All three sets of speeds were tested on two separate nights. Minidisc sound files were downloaded to computer and analysed using Bat Sound as per normal. This generated data on bat encounter rate at different driving speeds.

An additional experimental driving speed field trial was carried out in County Meath in June 2006. Five vehicles were driven one after the other at decreasing speeds along three, 1km transects. Each transect was driven 5 times at each speed. The speeds driven were 8mph (12.8kmph), 10mph (16kmph), 12mph (19.3kmph), 15mph (24.1kmph), 18mph (29kmph), which more accurately reflects the range of speeds driven by surveyors during the monitoring scheme. Transects were labelled A, B and C, each were located in County Meath. The first (A) was at Clogher Lane, Broomfield, Slane (Grid Ref: N980799). The second (B) was at The Sweep, valley of the River Devlin, Slane (Grid Ref: N982768) and the third (C) at Broad Bridge, Boyne Valley, Navan (Grid Ref: N920713).

Other Vertebrates

Other vertebrates were also recorded by surveyors. In 2006 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 58mile (93km) route on each survey evening.

RESULTS

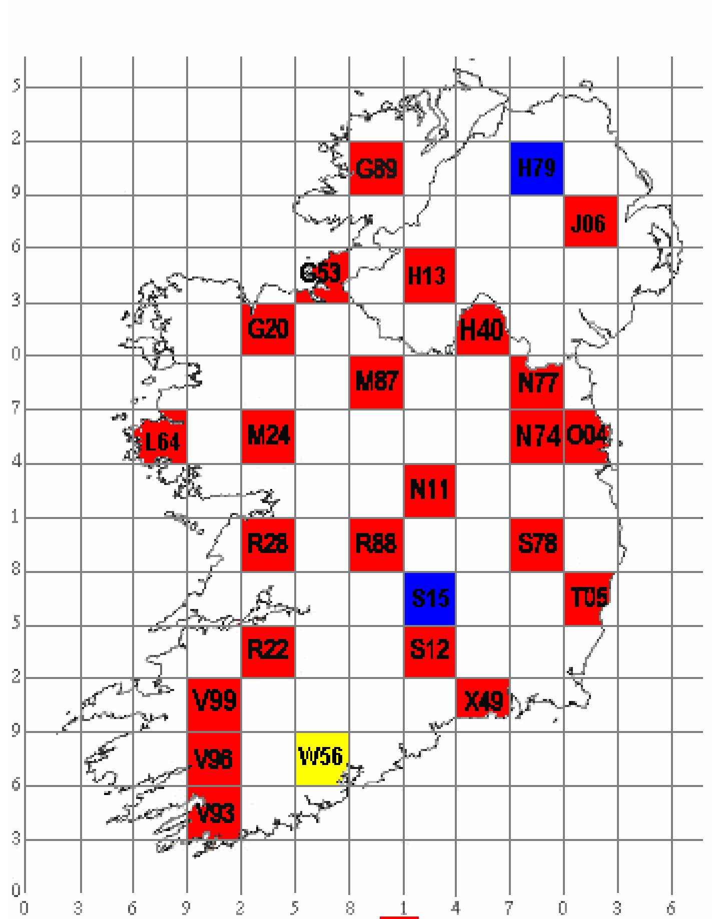


Figure 1. Squares in which surveys were carried out in 2006. Red indicates those 30km squares in which surveys were repeated. Blue squares were surveyed once in July and yellow squares were surveyed in mid-August.

Squares Covered in 2006

Seven teams participated in the 2003 pilot scheme and 17 survey routes were surveyed in 2004. Twenty one squares were surveyed in 2005 by 40 volunteers. An additional five squares were surveyed in 2006, bringing the total number of surveyed squares to 26 throughout the island. 59 volunteers participated in the 2006 scheme.

Survey work in 2006 was carried out from mid-July to the beginning of August and a repeat survey was carried out in mid-August. The median date of the first survey in 2006 was 24/7/06 (compared with 26/7/05 and 20/7/04). The median date of the second survey was 13/8/06 (compared with 15/8/05 and 13/8/04).

Transect coverage began 45 minutes after sundown.

A total of 26 squares were surveyed in 2006. Twenty three of these were repeated (49 night's field work), see Figure 1. This represents 1576km of monitoring transects driven and approximately 220hrs of surveyor time. Limited or no data were available from transects collected on four survey routes due to problematic detectors or leads (G20 Survey 1, G53 Survey 1, N74 Survey 1 and W56 Survey 2). Surveying in one square (O04, Survey 2) was abandoned half way due to bad weather. In general, the quality of data collected in 2006 was very good. Full datasets were available from 22 routes in July and 22 routes in August, 20 of which were repeat surveys. Squares that were surveyed in 2006 cover much of the Republic of Ireland, stretching from Donegal to Killarney to Wexford. Three squares in Northern Ireland cover parts of Fermanagh/Tyrone, Antrim and Londonderry.

In total 3211 bat encounters were recorded during the July and August 2006 surveys, from 887 independent monitoring transects. This compares with 1691 encounters that were recorded in July and August 2005 from 608 monitoring transects (i.e. 3.6 bat encounters per 1 mile/1.609km transect in 2006 compared with 2.78 in 2005). 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.

The mean time taken to complete a route (58miles/93km) in 2006 was 243 minutes (SD = 52.82, Min = 167, Max = 355), compared with 237 minutes in 2005, 233 minutes in 2004 and 231.4 minutes in 2003. The mean time taken to complete a monitoring transect (1mile/1.609km) varied between survey routes. On average it took 263 seconds to complete a transect in 2006, compared with 280 seconds in 2005 and 273 seconds in 2004. As the time expansion detector system only samples for $1/11^{th}$ of the time, there was an average total sampling time of 24.0 seconds per monitoring transect in 2006. Also, for every monitoring transect covered 0.146km (0.091 miles) were actually surveyed (i.e. $1/11^{th}$ of the distance).

Dataset Generated

The data shown in Table 1 below illustrates the overall number of times a bat call was recorded to minidisc during the 2006 surveys (with the previous 2 years for comparative purposes). 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 1 below.

Table 1: Raw bat encounter data, per 1 mile/1.609km transect, not corrected to encounters per km or per hour, Car-based Bat Monitoring Scheme 2006. Average number of bats reflects the average number of bat encounters observed during each 1 mile/1.609km transect travelled. Total Number of Transects = 887, in 2006, for all species. Also included is data for 2004 (total number of transects (n)=577 for pipistrelle, *Myotis* spp., total bats; n=597 for Leislers) and 2005 (n=608). Note that the detector records for just $1/11^{th}$ 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).

	Common pipistrelle	Soprano pipistrelle	Pipistrelle unidentified	Myotis spp.	Leisler's bat	Nathusius pipistrelle	Total Bats
Average no. per 1 mile transect 2004	1.905	0.695	0.443	0.050	0.511	0.000	3.621
Average no. per 1 mile transect 2005	1.344	0.574	0.266	0.035	0.544	0.001	2.781
Average no. per 1 mile transect 2006	**1.701**	**0.652**	**0.271**	**0.029**	**0.892**	**0.033**	**3.620**
Min per transect 2006	0	0	0	0	0	0	0
Max per transect 2006	21	11	8	2	22	5	47
SD 2006	±2.693	±1.359	±0.693	±0.199	±2.319	±0.265	±4.481
TOTAL ENCOUNTERS 2006	**1509**	**578**	**240**	**26**	**791**	**29**	**3211**

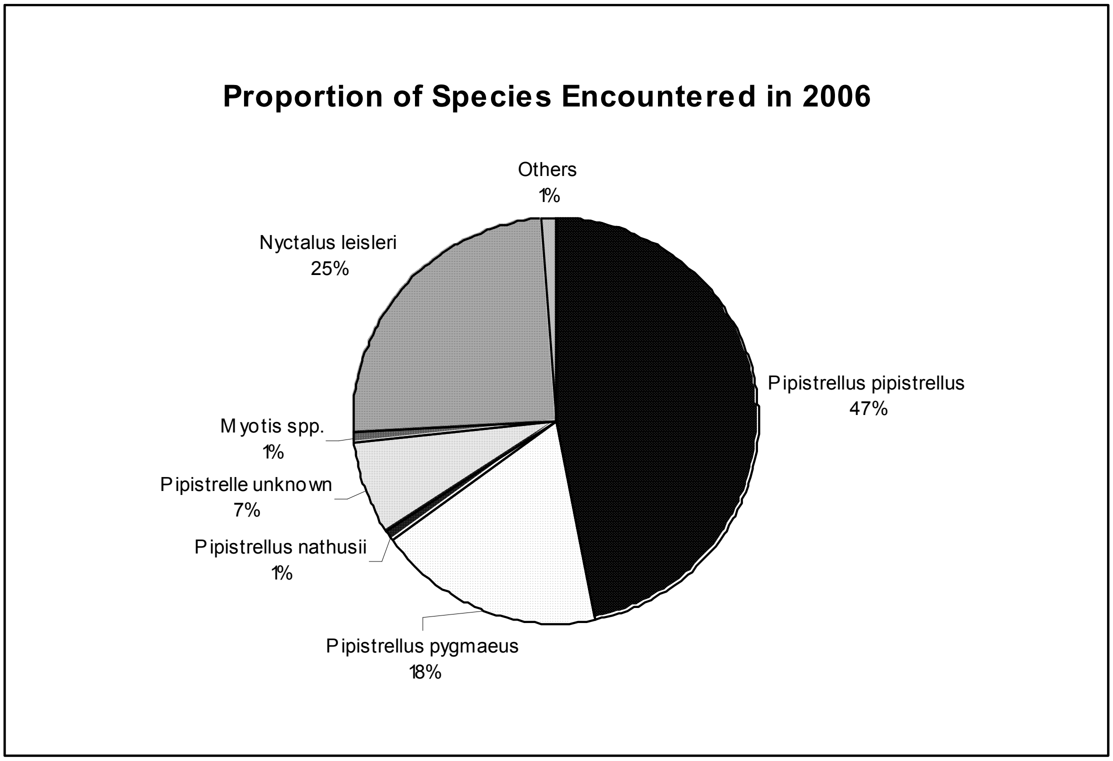


Figure 2: Proportion of species encountered during the 2006 survey. 'Other' refers to a number of calls that could definitely be ascribed to bats but could not be identified to species or species group, along with a number of *Plecotus auritus* (brown long-eared bat) social calls. A separate category for *Pipistrellus nathusii* (Nathusius' pipistrelle) has been added in 2006 to reflect the increased number of encounters with this species. 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.

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

Driving Speed Trial

In September 2005 an experiment was carried out using two cars driven repeatedly along a 500m transect in Co. Meath. Each car was driven at a different, known speed along the same transect – a slow car following a slightly faster car, for details see Methods above. This generated data on bat encounter rate at different driving speeds. Plots of mean bat encounter rates (per unit time or per unit distance) are shown with driving speeds (n=4).

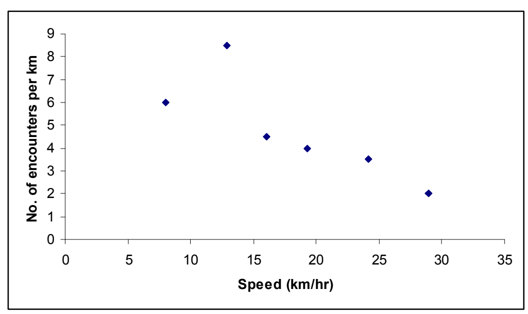


Figure 3: Mean bat encounter rate per km (n=4) from cars driven at varying speeds. Results from a speed trial carried out in September 2005 in the Broad Boyne Bridge, Co. Meath.

A plot of bat encounter rates per unit time indicates that this relationship between bat encounters and speed may be based upon the fact that transects driven at higher speeds take less time to complete, therefore fewer bats are observed, see Figure 4 below.

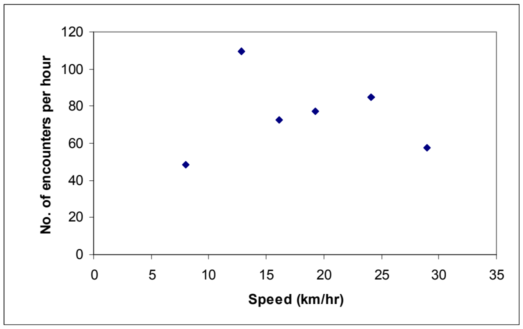


Figure 4: Mean bat encounter rate per hour (n=4) from cars driven at varying speeds (km/hr). Results from a speed trial carried out in September 2005 in the Broad Boyne Bridge, Co. Meath.

An additional experimental field trial was carried out in County Meath in June 2006. For precise methodology see Methods above. Results from the June 2006 this field trial are shown in Table 2 and Figures 5 and 6.

Table 2: Mean encounter rate for each transect during Speed Trial, Co. Meath, June 2006, n=5.

	Driving Speed - kmph				
Transect	**12.8**	**16.1**	**19.3**	**24.1**	**29.0**
A	1.4	0.4	1.2	1.6	0.4
B	n/a	0.8	0.25	1.8	0.6
C	6	3.8	1.8	2.6	2.2

Relatively low levels of bat activity were encountered at Transects A and B and no discernible patterns can be determined from these sites. At Transect C, however, higher numbers of bats were encountered. A plot of encounters per kilometre (Figure 5) indicates some negative correlation between encounter rate and speed.

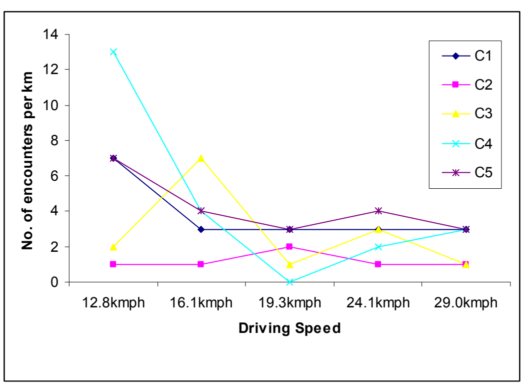


Figure 5: Mean bat encounter rate per kilometre from cars driven at different speeds at Transect C, Co. Meath, June 2006.

When this data is converted to encounter rate per hour, however, see Figure 6 below, the negative correlation is somewhat less evident.

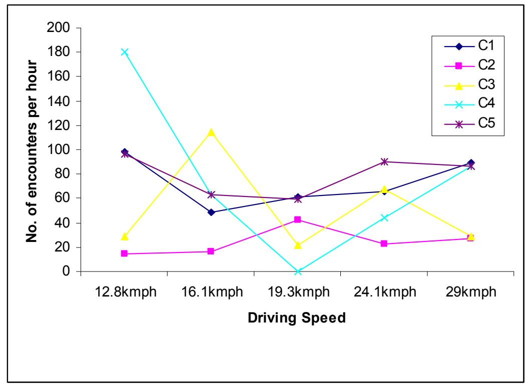


Figure 6: Mean bat encounter rate per hour from cars driven at different speeds at Transect C, Co. Meath, June 2006.

The results of this experiment indicate that predictable patterns between number of bats encountered and driving speed may be less likely to occur where overall bat activity levels are low (e.g. Transects A and B). However, where bat activity levels are higher (e.g. Transect C), there is a decrease in bat encounter rates (per unit distance travelled) with higher speeds. This effect can be counteracted by using encounter rate data per unit time for analysis.

Bat Encounters per Hour

From 2005, results were presented as number of encounters per hour of detector sampling time. Comparable results for 2006 are shown in Table 3 below.

For overall yearly trends, a Generalised Linear Model (GLM) with a Poisson error distribution has been applied to the data. Confidence intervals were generated by bootstrapping at Survey Square level. The number of encounters per survey were modelled, using the log of total number of 0.32second recordings per survey as a covariate, which is effectively similar to analysing the passes per minute, but allows use of a Poisson error distribution.

Since the annual estimates of overall bat abundance per survey depend on other factors in the model their values change somewhat from year to year. For example, in 2005 the estimate for the 2003 value for the common pipistrelle was 19.4 encounters per survey (20 transects), whereas in 2006 the encounter rate for 2003 is estimated to be 19.9 encounters per survey. This is due to new information from the 2006 data on the relative magnitudes of the site effects and the relationship with number of recording periods. To minimise these changes in the future, the value of 0.32ms recording periods used for the estimates has been standardised; all annual means are now predicted as if all squares had a total of 1,500 0.32second recording periods[1] (i.e. 75 periods per 1 mile transect). However, there will still be some minor changes in the future as a result of changes in the estimates for the sites (i.e. 30km squares).

[1] This variable has also been treated as an 'offset' with a fixed slope of 1.0. This is because when data consists of a count of a particular variable in different time intervals, the count can normally be expected to double if the amount of time doubles. This is equivalent to saying that the covariate of time should have a slope of 1.0 when working on the log scale. When the slope of the covariate is fixed at 1.0 in this way, it is known as an offset.

Table 3: Average number of bat encounters per hour for each survey square, Survey 1, 2006 (number of 1 mile transects (n) = 20 for each survey unless otherwise stated). Ppip = *Pipistrellus pipistrellus*, Ppyp = *Pipistrellus pygmaeus*, Pipun = Unidentified pipistrelle echolocating between 48 and 52kHz, Pnath = *Pipistrellus nathusii*, Nl = *Nyctalus leisleri*, Myotis = *Myotis* spp., Total = total number of encounters for all species. Means derived from total number of encounters divided by total time spent sampling by the time expansion detector, corrected to 1hr.

SURVEY 1 2006	Ppip/hr	Ppyg/hr	Pipun/hr	Pnath/hr	Myotis/hr	Nl/hr	Total/hr
G53 $^{n=5}$	3.4	20.2	3.4	0.0	0.0	3.4	33.7
G89	22.0	4.1	2.4	0.0	0.0	14.6	43.1
H13 $^{n=18}$	23.5	7.6	4.2	0.8	2.5	0.8	39.5
H40	21.1	11.7	3.5	0.6	0.0	4.1	41.0
H79	5.5	1.6	0.0	0.0	0.0	25.8	32.8
J06	12.2	5.7	0.8	5.7	0.0	54.4	80.3
L64	0.0	9.6	0.0	0.0	1.6	3.2	14.5
M24	23.8	19.3	0.7	0.0	0.0	5.2	50.6
M87 $^{n=19}$	7.3	12.9	10.6	0.0	0.0	17.1	47.9
N11 $^{n=18}$	19.8	3.8	3.8	0.9	0.9	23.5	54.6
N77	46.7	11.3	4.0	0.8	0.0	15.3	78.9
O04 $^{n=19}$	34.8	3.4	5.9	0.9	0.0	16.1	61.2
R22	60.1	32.3	12.7	3.2	1.3	8.4	119.5
R28	8.0	10.2	1.5	0.0	0.7	17.5	38.0
R88	48.6	2.6	6.8	0.0	0.0	17.9	76.8
S12	51.2	10.1	3.9	0.0	0.0	20.2	86.8
S15 $^{n=19}$	36.2	0.0	6.8	0.0	0.0	45.9	88.3
S78	62.4	13.7	11.1	1.7	0.0	31.6	121.4
T05	22.4	7.9	3.3	0.0	0.0	7.3	42.3
V93	17.2	4.9	3.3	0.0	0.0	19.6	45.0
V96	63.0	19.5	6.8	0.8	3.0	28.5	122.3
V99	57.8	12.8	6.4	0.0	0.0	8.8	86.6
X49	12.8	3.6	2.1	0.0	0.0	10.0	29.2
Average	**28.7**	**9.9**	**4.5**	**0.7**	**0.4**	**17.4**	**62.3**

Table 4: Average number of bat encounters per hour for each survey square, Survey 2, 2006 (number of 1 mile transects (n) = 20 for each survey unless otherwise stated). Ppip = *Pipistrellus pipistrellus*, Ppyp = *Pipistrellus pygmaeus*, Pipun = Unidentified pipistrelle echolocating between 48 and 52kHz, Pnath = *Pipistrellus nathusii*, Nl = *Nyctalus leisleri*, Myotis = *Myotis* spp., Total = total number of encounters for all species. Means derived from total number of encounters divided by total time spent sampling by the time expansion detector, corrected to 1 hr.

SURVEY 2 2006	Ppip/hr	Ppyg/hr	Pipun/hr	Pnath/hr	Myotis/hr	Nl/hr	Total/hr
G20	4.7	16.9	4.7	0.0	0.0	7.4	33.9
G53	6.9	10.0	2.3	0.0	0.0	0.8	20.7
G89	7.2	6.4	0.8	0.0	0.0	1.6	16.0
H13	12.2	11.4	3.5	0.0	0.0	4.4	31.5
H40	18.4	10.5	3.3	0.0	0.0	3.3	35.4
J06	2.9	4.3	2.2	4.3	0.0	7.2	21.6
L64	0.0	4.0	0.0	0.0	1.6	11.3	17.8
M24	7.7	8.4	5.1	0.0	0.6	1.3	23.2
M87 $^{n=19}$	13.3	11.2	2.8	0.0	0.0	3.5	30.7
N11	26.8	9.5	8.6	0.0	0.9	6.0	53.6
N74	31.3	5.5	3.1	0.0	0.0	2.3	47.0
N77	42.9	11.9	4.8	0.8	0.0	21.5	81.9
O04 $^{n=10}$	41.5	4.8	3.2	1.6	0.0	3.2	54.3
R22	41.8	11.2	5.6	0.0	0.7	13.2	73.2
R28	16.0	10.9	2.9	0.0	2.9	1.5	34.1
R88	49.2	7.6	4.2	0.0	0.0	26.3	88.2
S12	39.1	5.5	1.6	0.0	1.6	16.4	64.0
S78	49.3	27.0	7.2	0.0	0.8	30.2	115.2
T05	20.2	4.0	7.4	0.7	0.0	2.7	35.0
V93	19.8	0.8	0.0	0.0	0.0	17.3	37.9
V96	38.9	23.1	5.0	0.0	0.7	5.8	75.6
V99	29.9	7.1	4.3	0.0	0.0	29.2	70.5
X49	6.5	8.7	1.4	0.0	0.0	13.7	30.3
Average	**22.9**	**9.6**	**3.7**	**0.3**	**0.4**	**10.0**	**47.5**

Table 5: Average number of bat encounters per hour for all surveys, 2006. Ppip = *Pipistrellus pipistrellus*, Ppyp = *Pipistrellus pygmaeus*, Pipun = Unidentified pipistrelle echolocating between 48 and 52kHz, Pnath = *Pipistrellus nathusii*, Nl = *Nyctalus leisleri*, Myotis = *Myotis* spp., Total = total number of encounters for all species. Means derived from total number of encounters divided by total time spent sampling by the time expansion detector corrected to 1 hr.

All Surveys 2006	Ppip/hr	Ppyg/hr	Pipun/hr	Pnath/hr	Myotis/hr	Nl/hr	Total/hr
Overall Mean	25.78	9.75	4.07	0.50	0.43	13.68	54.91
Standard Deviation	±18.47	±6.75	±2.88	±1.16	±0.80	±12.01	±29.40
Minimum	0.00	0.00	0.00	0.00	0.00	0.77	14.45
Maximum	63.00	32.29	12.27	5.68	3.00	54.35	122.25

Common pipistrelle, *Pipistrellus pipistrellus* in 2006

The overall average number of *Pipistrellus pipistrellus* encounters per hour was 28.68 during Survey 1 in 2006 (see Table 3) compared with 22.89 during the second survey, see Table 4 (encounter rate per hour in 2005 was 17.02 during Survey 1 and 17.58 during Survey 2).

The overall average number of common pipistrelle encounters per hour for both months was 25.76, see Table 5 above. Common pipistrelles were the most frequently encountered species during the monitoring scheme in 2006 and in all years to-date. The common pipistrelle encounter rate (per km) for the island of Ireland in 2006 is 1.057. This compares with a slightly higher average encounter rate per km for the same months in Britain at 1.151 (courtesy of Russ *et al*., 2006).

REML (Restricted Maximum Likelihood Models) modelling allows statistical examination of the sources of variation in the data and the effects of some variables of interest. REML modelling of the common pipistrelle data was carried out. According to a REML model where repeat (or Survey number) is included as a covariate, this factor has no correlation with relative activity levels of common pipistrelles.

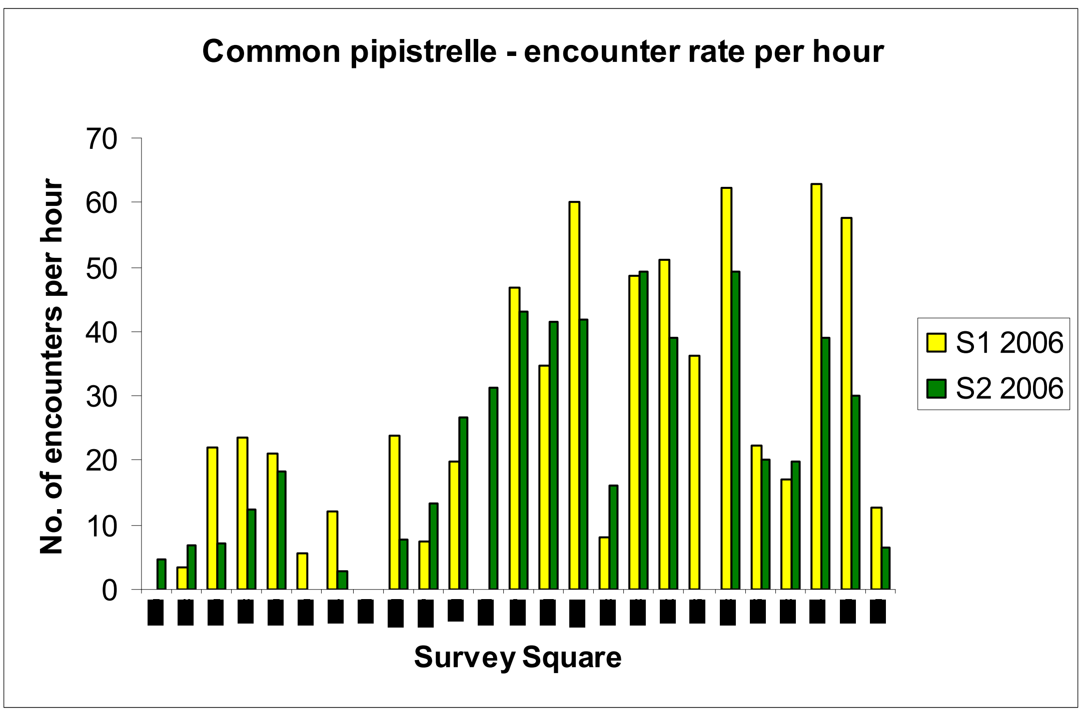


Figure 7: Average number of common pipistrelles, *Pipistrellus pipistrellus*, encountered (i.e. picked up on the detector and recorded to minidisc) per hour during July (S1) and mid-August (S2) in 2006.

Particularly high encounter rates were observed in R22, R88, S78 and during the first survey in V96 and V99. In L64, Connemara, no common pipistrelles were recorded in either 2005 or 2006, the two years when surveys have been carried out there. Encounter rates were generally lower in northern and western squares, with some exceptions, for example, X49, which is a southern square where few common pipistrelles were recorded. Low levels of activity were observed in G20, G53, J06, R28, and X49.

For common pipistrelles there is substantial variation in encounter rates between Survey Squares. Inclusion of squares in Northern Ireland, along with successful completion of a number of surveys in the North West this year, provided further evidence of North-South differences in common pipistrelle abundance. With Ordnance Survey grid reference eastings and northings fitted as covariates (in a REML model) there is a significant correlation between common pipistrelle abundance and geographic location on the island (northings, negative correlation: $p<0.001$; eastings, positive correlation: $p<0.001$,), with abundances higher to the east and falling to the north and west. This geographic difference can be seen illustrated in Figure 7 above, where bars to the left represent squares in the north west and those to the right are situated progressively more southerly.

Figure 8 below also provides an illustration of this variation across the country. Common pipistrelles may be absent from Connemara (L64) while S78, S12 and some of the squares in County Kerry (V99 and V96) are highlighted with particularly high levels of common pipistrelle activity.

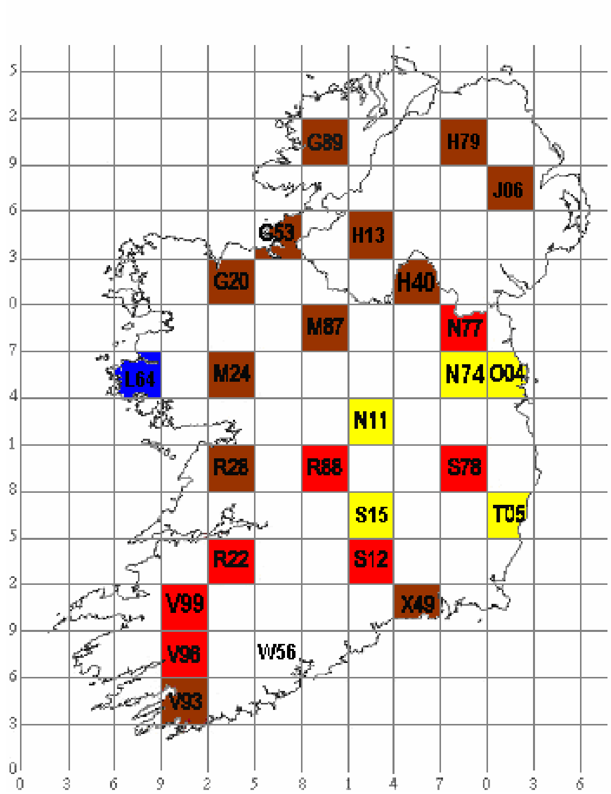


Figure 8: Survey squares colour coded according to common pipistrelle encounter rates (per hour). Map represents data from an average of the two surveys (where two are available), 2006. The overall average rate of common pipistrelle encounters for 2006 was 25.8/hr. Squares are not highlighted if no data is available.

- Absent.
- Encounter rate/km $>0\leq20hr^{-1}$
- Encounter rate/km $>20\leq39hr^{-1}$
- Encounter rate/km $>40hr^{-1}$

Additional information from REML models shows that transect number is also a highly significant factor correlating with common pipistrelle abundance and fitting a more complex curve suggests that this is because numbers are generally lower than average in the first few transects of each survey. This suggests that start time is an important factor for the surveys. Further discussion on this can be found in Discussion section.

Yearly Activity

Figure 9 below shows mean common pipistrelle passes per survey, adjusted to represent the situation if all surveys had the average number of 0.32ms recordings. The approach used is a

Poisson Generalized Linear Model (GLM see Glossary) with bootstrapped confidence limits 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 a covariate (Covariate see Glossary) but allows use of a Poisson error distribution (also see Glossary).

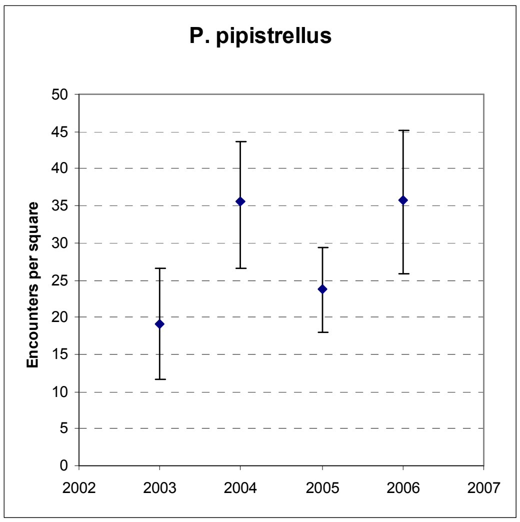


Figure 9: Results of the GLM model for encounters of common pipistrelles per survey. Bars are 95% bootstrapped confidence limits.

The year 2006 had the highest average common pipistrelle encounters per survey of all four survey years since 2003. In 2003, lower encounter rates may have arisen from later survey dates, lower number of survey squares and an earlier starting time. In 2005 lower encounter rates observed in that year compared with 2004 were hypothesised to have resulted from slightly different survey dates, i.e. the median date of Survey 1 2005 (26/07/05) was 6 days later than the median Survey 1 date in 2004 (20/07/04). By way of contrast, however, the median survey date for Survey 1 in 2006 was just two days earlier than in 2005 (24/07/06), but bat encounter rates were considerably higher. Yearly fluctuations are therefore likely to be the result of factors other than relatively small differences in survey dates.

Given the oscillating annual pattern and large confidence limits, no discernible trend in common pipistrelle abundance can be deduced from the data as yet.

Temperature Analysis

Mean monthly temperatures for July and August from climatological stations within or closest to each survey square were included in linear regression analysis with common pipistrelle encounter rates per hour (logged) from each square for the years 2004 to 2006.

No significant relationship was found between common pipistrelle activity levels and temperature when data for all squares were included.

A Linear Model including common pipistrelle activity (means per Survey Square, for each year) as the dependent variable, temperature data, and Survey Squares as a covariate, indicates that there is a significant correlation between pipistrelle activity and mean air temperature once the effects of Survey Square have been accounted for ($p<0.001$). The relationship between common pipistrelle activity and temperature is a positive one.

Soprano pipistrelle, *Pipistrellus pygmaeus,* in 2006

The overall average number of *Pipistrellus pygmaeus* encounters per hour was 9.9 during Survey 1 in 2006 and 9.6 during the second survey (2005 Survey 1 encounter rate was 6.89 and 2005 Survey 2 was 7.87). Where the Survey number is included as a covariate in REML analysis, results show that there is no significant relationship between Survey and soprano pipistrelle activity levels. The overall average number of soprano pipistrelle encounters per hour for both months was 9.75 (7.39 encounters per hour in 2005), see Table 5 above.

The soprano pipistrelle encounter rate (per km) for the island of Ireland in 2006 is 0.405. This compares with a slightly lower average encounter rate per km for the same months in Britain in 2006 at 0.300 (courtesy of Russ *et al*., 2006).

The soprano pipistrelle was the third most frequently encountered species during the monitoring scheme in 2006 with common pipistrelles and Leisler's bat more frequently encountered. In previous years the relative abundance of soprano pipistrelles was second only to common pipistrelles with Leisler's bat the third most frequent species.

Particularly high encounter rates were observed in 2006 in R22 (Survey 1), S78 (Survey 2) and V96, both surveys (see Figures 10 and 11). V96 also saw very high soprano pipistrelle activity levels in 2005. Particularly low levels of activity were observed in S15 (where the species was absent during the survey carried out in July), V93, H79 and R88 (Survey 1). This was the only pipistrelle species confirmed in 2006 and 2005 in L64, the two years when surveys have been carried out there.

In general, encounter rates for this species tend to be somewhat higher in certain western survey squares. REML modelling indicates that this negative relationship between encounter rates and grid reference eastings is not quite significant (p=0.09). There is no relationship between soprano pipistrelle abundance and northings (p=0.852).

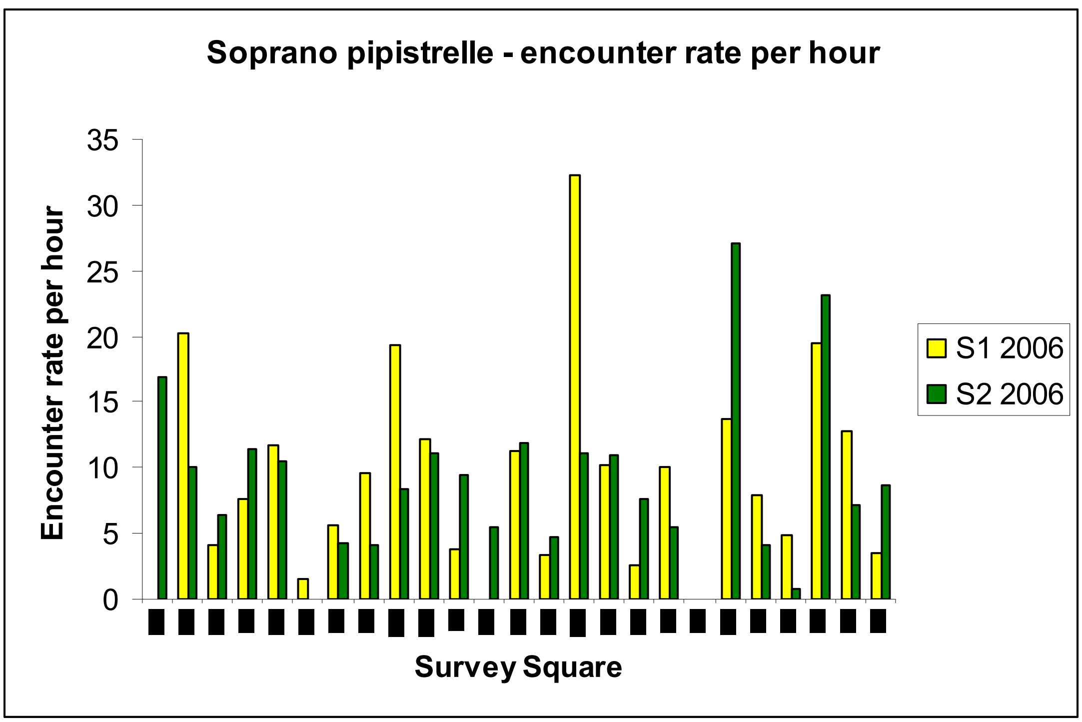


Figure 10: Average number of soprano pipistrelles, *Pipistrellus pygmaeus*, encountered (i.e. picked up on the detector and recorded to minidisc) per hour during July (Survey 1) and August (Survey 2) in 2006.

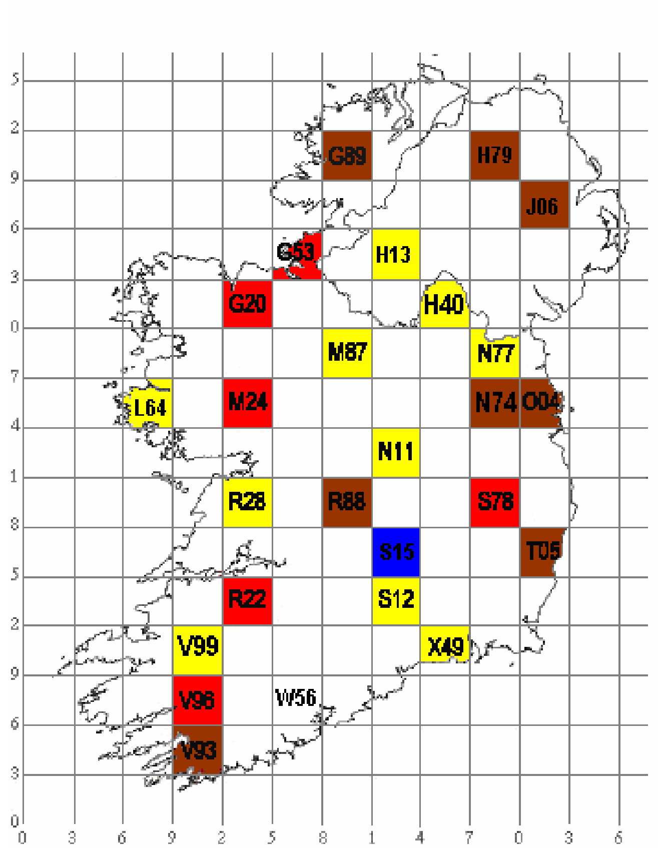


Figure 11: Survey blocks colour coded according to soprano pipistrelle encounter rates (per hour). Map shows average data from both surveys 2006 where data for both surveys is available. The overall average rate of soprano pipistrelle encounters for 2006 was 9.75hr^{-1}. Squares are not highlighted if no data is available.

- Absent (Survey 1 was carried out in S15 in 2006).
- Encounter rate/km >0≤6hr^{-1}
- Encounter rate/km >6≤12hr^{-1}
- Encounter rate/km >12hr^{-1}

Yearly Activity

Figure 12 below shows mean soprano pipistrelle passes per survey, adjusted to represent the situation if all surveys had the average number of 0.32ms recordings. The approach used is a Poisson Generalized Linear Model (GLM see Glossary) with bootstrapped confidence limits 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 a covariate (Covariate see Glossary) but allows use of a Poisson error distribution (also see Glossary).

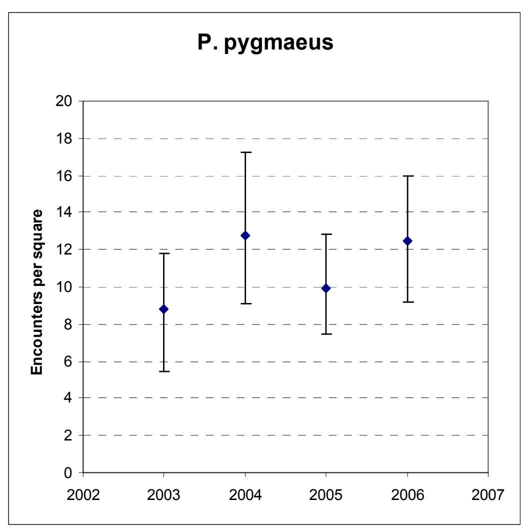


Figure 12: Results of the GLM model for encounters of soprano pipistrelle per survey. Bars are 95% bootstrapped confidence limits.

The year 2006 had higher average soprano pipistrelle encounters per survey than 2005 but slightly lower average encounters per survey than 2004. In 2003, particularly low encounter rates may have arisen from slight differences in methodology. In 2005 it was hypothesised that lower encounter rates than the previous year may have resulted from slightly different survey dates, i.e. the median date of Survey 1 2005 (26/07/05) was 6 days later than the median Survey 1 date in 2004 (20/07/04). By way of contrast, however, the median survey date for Survey 1 in 2006 was just two days earlier than in 2005 (24/07/06), but bat encounter rates were considerably higher. Yearly fluctuations are therefore likely to be the result of factors other than relatively small differences in survey timing.

Given the oscillating annual pattern and large confidence limits, no discernible trend in soprano pipistrelle abundance can be deduced from the data as yet.

Temperature Analysis

Mean monthly temperatures for July and August from climatological stations within or closest to each survey square were included in linear regression analysis with soprano pipistrelle encounter rates per hour (logged) from each square for the years 2004 to 2006.

No significant relationship was found between soprano pipistrelle activity levels and temperature when data for all squares were included.

A Linear Model including soprano pipistrelle activity (means per Survey Square, for each year) as the dependent variable, temperature data, and Survey Squares as a covariate, indicates that there is no significant correlation between soprano pipistrelle activity and mean air temperature once the effects of Survey Square have been accounted for.

Ratio of Common Pipistrelle to Soprano Pipistrelle Activity

Overall in 2006, as in previous years, higher common pipistrelle activity was recorded, compared with soprano pipistrelle activity (see Figure 13 below). Note that making a direct comparison between encounter rates for these two species is based on the assumption that both produce echolocation calls that are equally detectable, which is not strictly true (for a more detailed discussion of this topic see Roche *et al.* (2006)). Due to effects of attenuation of high frequency echolocation sounds there may be a bias towards detection of the common pipistrelle. An accurate prediction of relative detectability of the two species cannot be directly applied to data from the present project.

In 2006, on average 2.67 times the number of common pipistrelle encounters (per hour) were recorded compared with soprano pipistrelles. This compares with 2.3 and 4.1 times the number of common pipistrelle encounters to soprano pipistrelles in 2005 and 2004 respectively. Exceptionally high levels of soprano pipistrelle activity relative to common pipistrelle activity were observed in a number of survey squares north west of the Shannon. This arises due to a decrease in common pipistrelle activity in the north and west. Soprano pipistrelles tend, by way of contrast, to be somewhat more abundant in the west.

Of particular interest is L64, Connemara, where no common pipistrelles were recorded on either survey. X49, as in previous years also shows high levels of soprano pipistrelle activity compared with common pipistrelles.

At Survey Square level there are geographic differences in relative abundance of the two species. However, when REML modelling is carried out with grid reference easting and northings included as covariates, the correlation between the two species is actually a positive one (0.318), although not significant. This would appear to indicate that, once geographic trends are accounted for, squares that have high levels of one species are also likely to have high levels of the other.

....

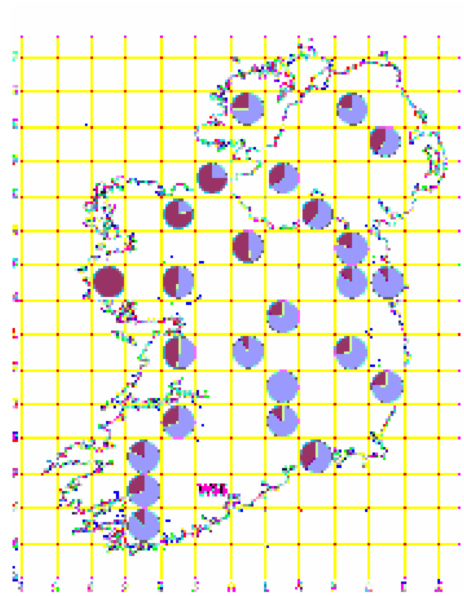


Figure 13: Pie charts illustrating relative encounter rates – per km – of common pipistrelles blue and soprano pipistrelles burgundy for both Surveys, 2006. Relatively higher activity levels of common pipistrelles compared with soprano pipistrelles can be observed in most squares except the north west. Squares have no pie charts if no data is available.

Leisler's bat, *Nyctalus leisleri*, in 2006

The overall mean number of *Nyctalus leisleri* encounters per hour for Survey 1 2006 is 17.4. The mid-August (Survey 2) average was 10 encounters per hour. The overall average for both months in 2006 was 14.22. REML analysis of Leisler's data since 2003 indicates a significant relationship (p=0.044) between encounter rates and Survey (1 or 2), with greater encounter rates observed during Survey 1 than Survey 2.

The Leisler's bat encounter rate (per km) for the island of Ireland in 2006 is 0.554. This compares with a much lower average encounter rate per km for the same months in Britain in 2006 at 0.022 (courtesy of Russ *et al*., 2006).

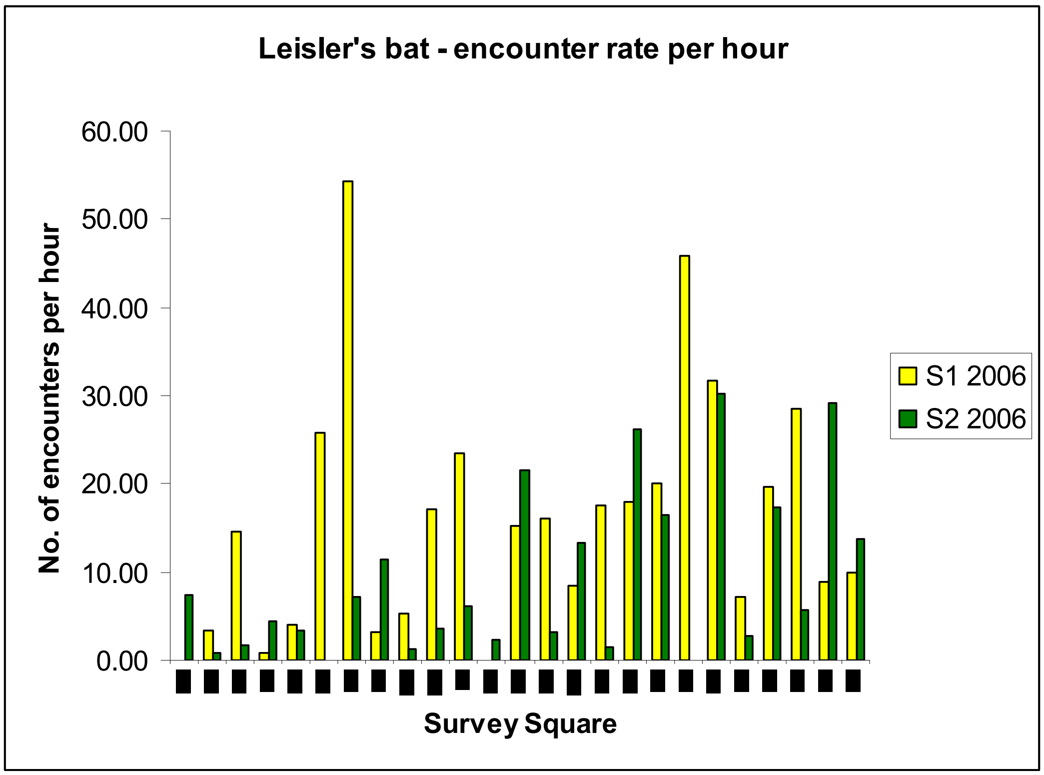


Figure 14: Average number of Leisler's bats, *Nyctalus leisleri*, encountered (i.e. picked up on the detector and recorded to the minidisc) per hour during July (Survey 1) and mid-August (Survey 2) in 2006.

.

Particularly high Leisler's bat encounter rates were observed in J06 (Survey 1), S15 (Survey 1), and S78 (both Surveys) (see Figure 14). Low encounter rates were recorded from G53, H13, N74 and H40.

Figure 15 provides an indication of particularly high encounters rate survey squares for 2006. REML analysis indicates a significant, positive correlation between Leisler's encounter rates and eastings (p=0.004), with greater encounters in the east of the country. In addition, REML analysis indicates a significant relationship between northings and encounter rates, with higher encounter rates, on average, in the south of the country (p=0.002). There is also an interaction of borderline significance between eastings and northings, with the north-south trend being less obvious in the east.

Changes in activity distribution between Survey 1 and Survey 2 that were observed in previous years (e.g. increases in encounter rates in coastal squares during Survey 2) were not noted in 2006. Instead, an overall decrease in encounter rates was noted from Survey 1 to Survey 2.

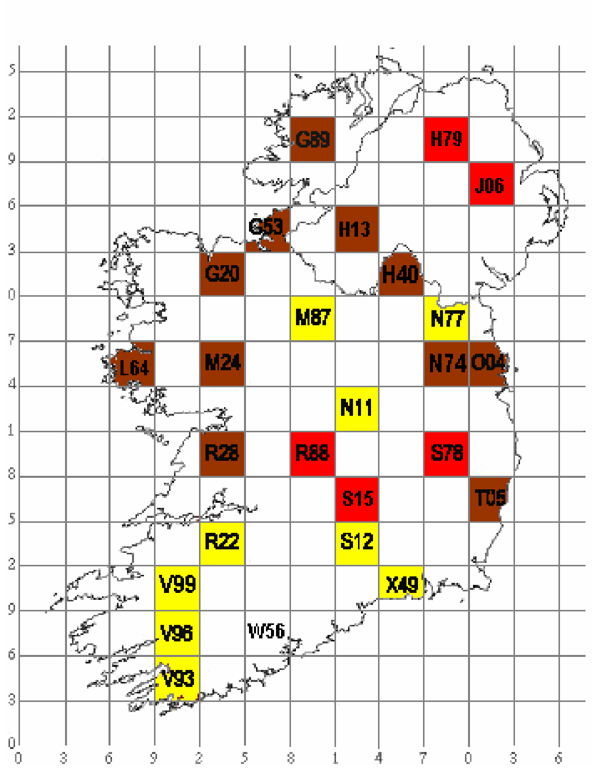


Figure 15: Survey blocks colour coded according to Leisler's bat encounter rates (per hour). Map represents average data from both Survey 1 and Survey 2 2006 where data from two surveys are available. The overall average rate of Leisler's bat encounters for 2006 is14.22hr^{-1}. Squares are not highlighted if no data is available.

Absent.
Encounter rate/km $>0\leq10$hr^{-1}
Encounter rate/km $>10\leq20$hr^{-1}
Encounter rate/km >20hr^{-1}

Yearly Activity

Figure 16 below shows mean Leisler's passes per survey, adjusted to represent the situation if all surveys had the average number of 0.32ms recordings. The approach used is a Poisson Generalized Linear Model (GLM see Glossary) with bootstrapped confidence limits 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 a covariate (Covariate see Glossary) but allows use of a Poisson error distribution (also see Glossary).

The year 2006 had higher average encounters per survey than any survey year to date. Low encounter rates in 2003 may reflect later survey dates, a low number of squares surveyed and earlier survey start times than in 2004 and 2005.

2006 was the first year where Leisler's bat was the second most frequently encountered bat species.

Figure 16 below indicates that Leisler's bat abundance may be showing an increasing trend.

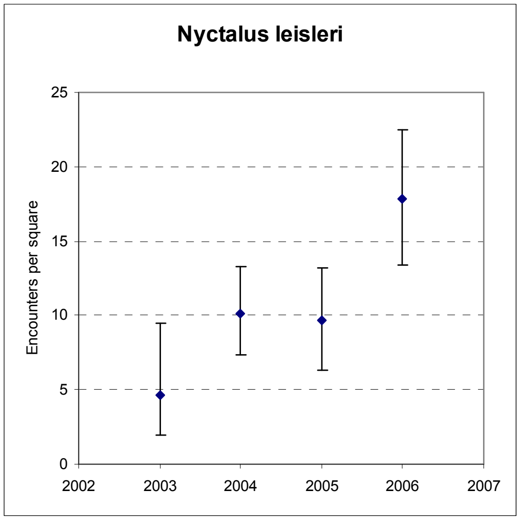


Figure 16: Results of the GLM model for Leisler's bat encounters per survey. Bars are 95% bootstrapped confidence limits.

Temperature Analysis

Mean monthly temperatures for July and August from climatological stations within or closest to each survey square were included in linear regression analysis with Leisler's bat encounter rates per hour (logged) from each square for the years 2004 to 2006.

A highly significant positive relationship was found between Leisler's bat activity levels and temperature when data for all squares were included ($p<0.0001$).

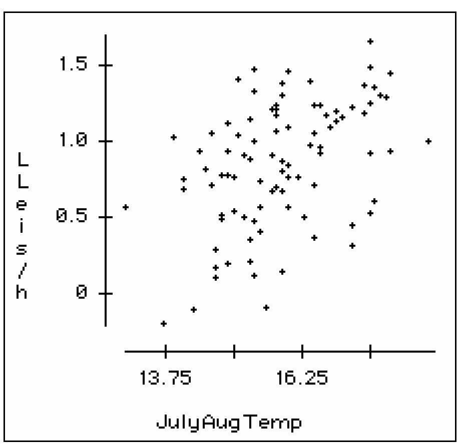


Figure 17: A plot of average monthly air temperatures at climatological stations within or close to survey squares and average Leisler's bat encounter rates per hour (logged) from each Survey Square from 2004 to 2006.

A Linear Model (ANOVA with covariates) including Leisler's bat activity (means per Survey Square, for each year) as the dependent variable, temperature data, and Survey Squares as a covariate, indicates, however, that there is no significant correlation between Leisler's bat activity and mean air temperature once the effects of Survey Square have been accounted for. This result indicates that the positive correlation (whether meaningful or spurious) is between the spatial distribution of Leisler's bat and the spatial pattern of temperatures, rather than a relationship between activity and temperature within the specific time period.

Nathusius pipistrelle, *Pipistrellus nathusii,* in 2006

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. By 2005 it had been recorded by detector as far south as Killarney National Park (C. Kelleher *pers. comm.*).

The car-based bat monitoring results for 2006 saw a dramatic increase in Nathusius pipistrelle encounters across the country. 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 have been surveyed every year since, but Nathusius pipistrelle was recorded in each in 2006 for the first time.

Mean encounter rate (per hour) for Nathusius pipistrelles was 0.67 in Survey 1 and 0.3 for Survey 2 in 2006. Overall mean hourly encounter rate for 2006 was 0.5. The highest encounter rate with Nathusius pipistrelles was in Square J06, Northern Ireland, where encounter rates were consistently high in both surveys. In R22, Limerick, where a relatively high number of encounters were recorded in Survey 1, the species was not recorded in Survey 2. In most squares, just a single sequence of echolocation calls, consisting of 2 to 4 pulses, was recorded.

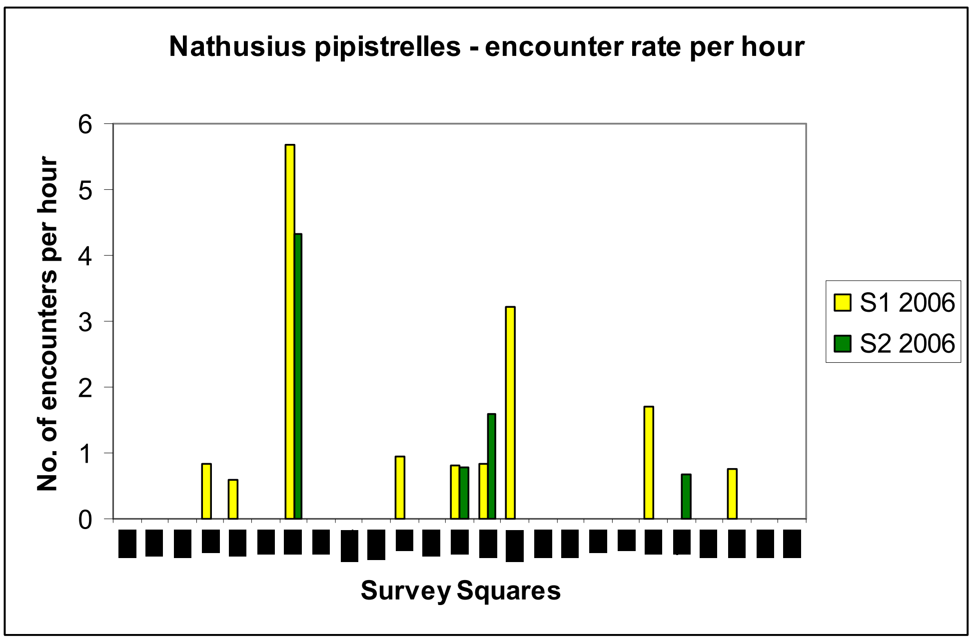


Figure 17: Average number of Nathusius pipistrelle bats, *Pipistrellus nathusii*, encountered (i.e. picked up on the detector and recorded to the minidisc) per hour during July (Survey 1) and mid-August (Survey 2) in 2006.

Most of the records for Nathusius pipistrelles from the 2006 car-based bat monitoring scheme are located in the eastern half and the south west of the island. See Figure 18 below for details.

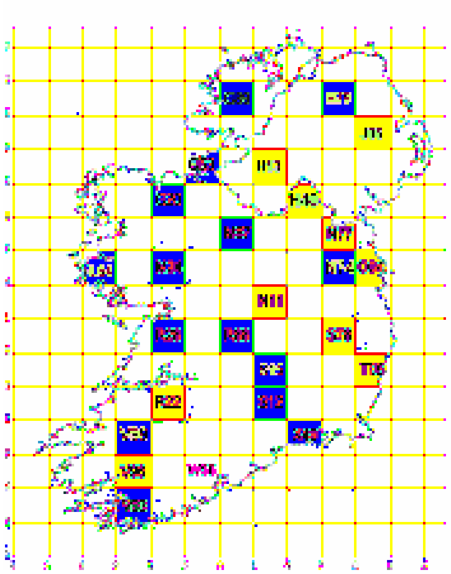


Figure 18: Survey blocks colour coded according to Nathusius pipistrelle records in 2006, both surveys. Locations where Nathusius pipistrelles occur are highlighted in yellow. Blue squares indicate an absence of records. Squares are not highlighted if no data is available

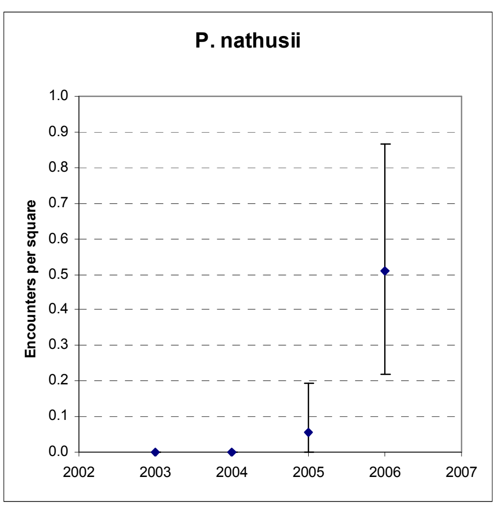


Figure 19: Results of the GLM model for Nathusius pipistrelle encounters per survey. Bars are 95% bootstrapped confidence limits.

Despite an overall low occurrence of Nathusius pipistrelle in the car monitoring scheme, Figure 19 does indicate an upward trend for the species. In addition, from the limited evidence available the species may be undergoing an expansion of its range throughout the country.

A similar increase in Nathusius pipistrelle encounters was recorded from the car-based bat survey in Britain in 2006; the number of encounters with this species increased from 4 in 2005 to 39 in 2006 (Russ *et al.* 2006).

***Myotis* bats in 2006**

Overall mean number of *Myotis* encounters per hour for Survey 1 in 2006 was 0.44. The Survey 2 average is 0.43 encounters per hour. The overall average for both surveys in 2006 is 0.43 encounters per hour, see Table 3 above.

The average number of *Myotis* bat encounters per hour for the two survey months is not plotted because of the low number of occurrences.

Myotis bats were recorded from 9 of the 25 squares surveyed in 2006, see Figure 20. Locations of *Myotis* bat records from the 2006 car-based bat monitoring scheme were widely distributed throughout the country although absent, in 2006, from squares along the eastern seaboard.

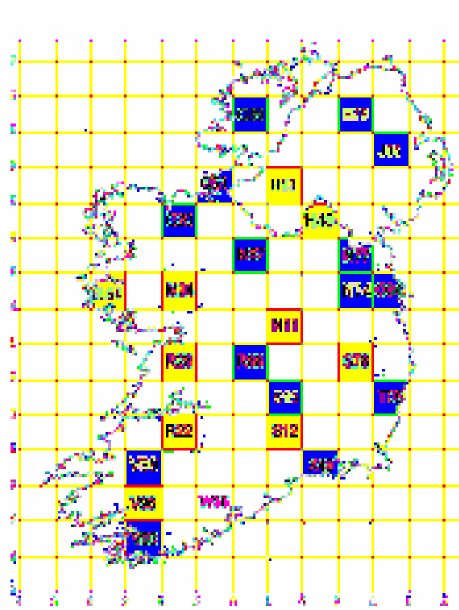


Figure 20: Survey blocks colour coded according to *Myotis* bat records in 2006, both surveys. Locations where *Myotis* bats occur are highlighted in yellow. Blue squares indicate an absence of records. Squares are not highlighted if no data is available.

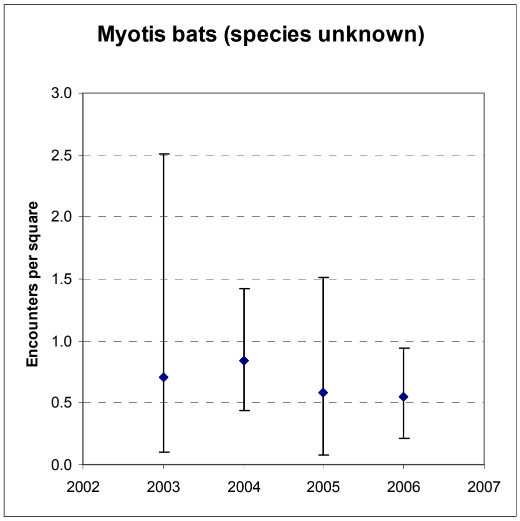


Figure 21: Results of the GLM model for encounters per survey. Bars are 95% bootstrapped confidence limits.

On account of very low encounter rates no particular patterns are discernible from the Myotis species data.

Brown long-eared bat, *Plecotus auritus*, in 2006

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). These social calls were recorded on three occasions in 2005 and 21 times in 2006. Locations of Survey Squares where the species was recorded making social calls in 2006 are shown in Figure 22.

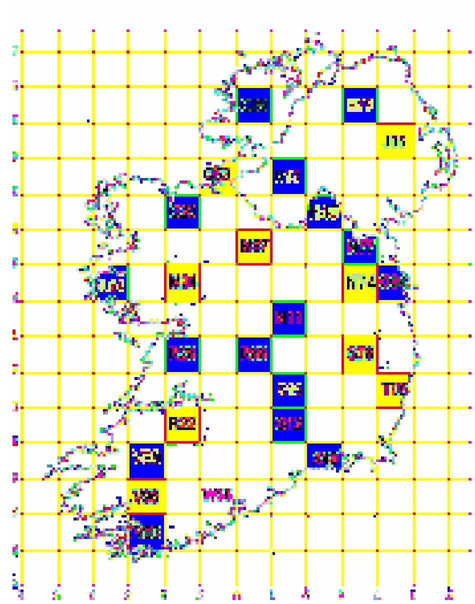


Figure 22: Survey blocks colour coded according to long-eared bat social call records in 2006, both surveys. Locations where long-eared bats occur are highlighted in yellow. Blue squares indicate an absence of records. Squares are not highlighted if no data is available.

Activity Hotspots

Average encounter rates for particular survey squares are subject to a high level of random variation during each survey. However, two squares had particularly high average encounter rates from 2004 to 2006; R22 (Limerick) and S78 (Carlow, Kildare and Wicklow). The average total bat encounter rate per hour was 81.98 in the former (n=4) and 88.91 (n=6) in the latter. This compares with an overall average of 50.06 per hour from all Survey Squares.

OTHER VERTEBRATES

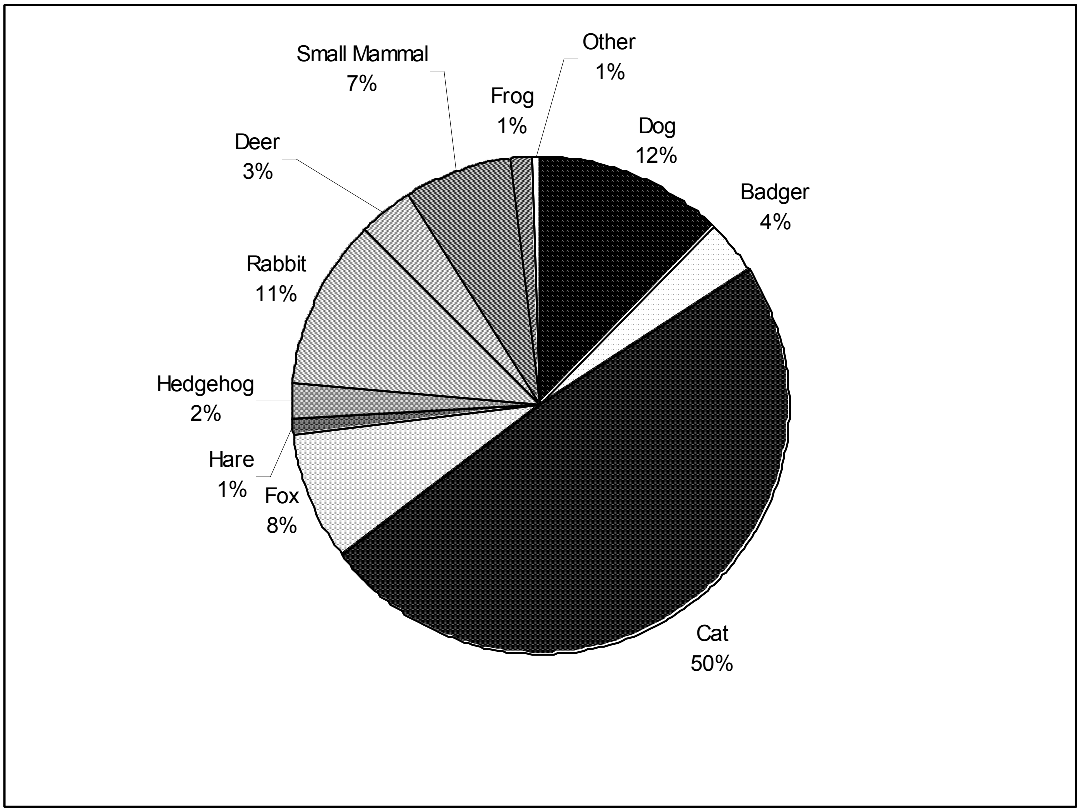


Figure 25: Living vertebrates, other than bats, observed during Survey 1 and Survey 2, 2006, n=322. Small mammals category includes mice, rats, pygmy shrews, voles and unidentified small mammals. Others include long-eared owl and stoat. Note also that sika and red deer are grouped together for the purposes of this chart.

Recording of other vertebrates was carried out throughout the survey, during and between transects in 2006. This clarification of methodology, along with an increase in the number of surveys carried out, resulted in a rise in the number of other vertebrates recorded. In 2006, 322 living specimens were recorded compared with 80 in 2005 and 62 in 2004. In addition 28 dead specimens were noted in 2006, compared with just 4 in 2005.

In total, 4199km of roads were surveyed for vertebrates other than bats in July and August 2006. Of particular interest in 2006 was the high number of cats observed during both surveys; cats constituted 50% (n=157) of all living vertebrates observed. By way of contrast, cats only constituted 11% of the dead specimens observed by surveyors (see Figure 26). Also of interest was the high number of dogs recorded, n=39. Rabbits were the third most frequently recorded ‘other vertebrates’ species, n=36. Foxes were also relatively common, n=27. No pine-martens or minks were recorded in 2006.

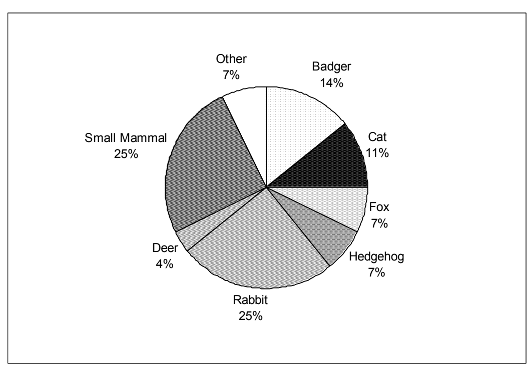


Figure 26: Dead vertebrates, other than bats, observed during Survey 1 and Survey 2, 2006, n=28. Small mammals category includes mice and rats.

DISCUSSION

Common and Soprano Pipistrelles

The two sibling species of pipistrelle are well represented on the car transect monitoring project. Overall activity levels of the two pipistrelles increased in 2006 compared with 2005.

The common pipistrelle is the most frequently encountered species by the car-based bat monitoring scheme. It is distributed widely throughout the country but in 2005 and 2006 it was absent from the survey square in Connemara (L64) during all surveys conducted there. This species is significantly correlated with grid reference eastings and negatively correlated with northings. It is less frequently encountered in the north west although it does occur in the region. Common pipistrelle activity levels (2004-2006) show a significant positive correlation with mean air temperatures when the effects of Survey Square have been accounted for.

Soprano pipistrelles are generally most active in squares to the west of the country, particularly north-west of the Shannon although this negative correlation with grid reference eastings is not significant at a 95% level (REML analysis). Activity levels of soprano pipistrelles were not shown to have any correlation with air temperature (with or without Survey Square included as a covariate).

Across Europe, both species have been found to be widely distributed (see, for example, Mayer and Von Helverson 2001) but common pipistrelles are largely absent in Scandinavia, apart from in southern Denmark (Baagoe 2001). Common pipistrelles are the more common species in central Europe (Mayer and Von Helverson 2001). Soprano pipistrelles are found throughout Europe but are particularly abundant in the north and around the Mediterranean. Since the distribution range of the two species overlaps over a huge geographic area the two species are considered to differ in ecology, otherwise competitive exclusion of one or other species could be expected (Mayer and Von Helverson 2001).

Ecological studies have indicated that the soprano pipistrelle may favour riparian habitats for foraging (e.g. Oakely and Jones 1998; Russ and Montgomery 2002; Vaughan, *et al*. 1997). Davidson-Watts *et al*. (2006) investigated the hypothesis that the soprano pipistrelle is more selective in the habitats it uses than the common pipistrelle. Using the results of a radiotracking study of various colonies in Britain, Davidson-Watts *et al*. (2006) found evidence to support this hypothesis by showing that soprano pipistrelles actively selected riparian and riparian woodland habitats for foraging while common pipistrelles, although preferring deciduous woodland, foraged in a wider selection of habitats. In addition, the common pipistrelle was found in the Davidson-Watts study, to have larger core foraging areas than the soprano pipistrelle, perhaps linked to its generalist foraging strategy.

The common pipistrelle has shown a significantly increasing trend from the UK National Bat Monitoring Programme Field Surveys carried out since 1998 by The BCT (Bat Conservation Trust, 2005). The soprano pipistrelle, on the other hand, has shown no significant trend, up or down. Insufficient data is available from Ireland to determine trends for these two species here.

Common and Soprano Pipistrelles and Climate Change

Should mean air temperatures continue to rise in Ireland because of global climate change it is hypothesised that this may have a knock-on effect of increasing invertebrate abundance for the common pipistrelle. As a result, populations of the common pipistrelle, a generalist forager, could be expected to increase in the medium term.

Such a prediction does not, however, take into account the possibility of increased competition for roosting or prey resources from new migrants or resident bat species. *Pipistrellus kuhlii*, for example, a similar sized species to the common and soprano pipistrelles, has recently been confirmed resident on the UK Jersey islands (Magris 2003). This was formerly considered to be a Mediterranean species but appears to be expanding its range northwards (e.g. Robinson *et al*. 2005). The hypothesis of increased temperature resulting in increased available prey also does not take into account the potential for habitat changes and/or loss as a result of changing agricultural practices with higher temperatures. In addition, the hibernation requirements for the common pipistrelle are little known in Ireland, so the effects climate change may have on this are also unknown.

Changes in population trends of the soprano pipistrelle as a result of climate change are equally complicated to predict since this species selects riparian areas and is more frequent in areas of high rainfall (in the west of Ireland). Changes to overall levels of precipitation and increased occurrence of summer droughts may therefore be of greater relevance for population trends of this species.

Leisler's Bat

This species was recorded from all Survey Squares in 2006. Overall activity levels of Leisler's bats increased in 2006 compared with previous years of surveying. From the limited available evidence it appears that the Leisler's bat population in Ireland may be showing an increasing trend. If true, this would be of particular conservation significance since the Leisler's bat is rare in other parts of Europe but relatively frequent in Ireland.

Activity levels of Leisler's bat showed a highly significant positive relationship with mean air temperature until Survey Squares were included as a covariate in the analysis, at which point the relationship became non-significant. This may indicate that the correlation is between the spatial pattern of temperatures and the spatial pattern of Leisler's bat rather than a relationship between activity and temperature in the corresponding time period.

The potential impact of increasing air temperatures as a result of climate change on the Irish Leisler's bat population is unstudied to date. These initial results of temperature correlations on the Leisler's bat abundance appear to indicate that air temperature impacts overall activity distribution of the bat within the island. It may be hypothesised that increased abundance of the bat may be expected in more north or westerly counties should temperatures continue to rise. Leisler's bat may, however, be at particular risk from increased competition from large, strong flying bat species should such species become new residents or regular migrants to Ireland.

Nathusius' Pipistrelle

This species was recorded for the first time by the car 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. Available evidence appears to indicate an upward trend in the Nathusius population and an expansion across the island. The species has not been recorded by the car-based bat monitoring scheme at locations west of the Shannon to date, although there are detector records for the species from May 2006 at Cong, Co. Mayo (BCIreland Bat Database).

It was not possible to carry out correlation analyses with Nathusius pipistrelle activity levels and air temperature, because its activity levels are still too low. However, it is possible that rising air temperatures are in some way contributing to the currently expanding population within the island. A similar increase in Nathusius pipistrelle abundance was recorded in the UK in 2006 (Russ *et al.* 2006).

***Myotis* Bats**

As in previous survey years small numbers of *Myotis* bats were encountered. 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.

Brown Long-eared Bat

This species was recorded for the first time in 2005 and 2006 saw an increase in the number of social calls recorded from this species. Number of encounters is still too low to determine population trends, however.

Activity Hotspots

Squares R22 (Limerick) and S78 (Carlow /Kildare /Wicklow) were identified as squares where particularly high encounter rates were recorded in most years to date. Further examination will be made, in 2007, of high encounter rate squares.

PROPOSALS FOR 2007

Methodology

Continue as at present surveying each square twice yearly with additional squares proposed for Northern Ireland to bring the coverage of squares to a similar level to that in the Republic. Additional survey work may be proposed at intervals throughout the year in a number of selected squares to match surveys carried out in Britain. Sonogram analysis should continue as at present with rigorous quality control.

Statistical Analysis

From 2007 statistical analysis will include temperature and start-time variables in the REML models to further investigate their relationship with bat activity. If significant, these variables could be used as covariates in the GLM models.

Equipment

Trials will be carried out in 2007 using rechargeable batteries to improve the environmental sustainability of the scheme.

Volunteer Training and Feedback

Training will take place as in 2006 and volunteers will be reminded of survey start times via email.

Feedback will take the form of a 'thank you' email listing numbers of bat encounters and a breakdown of species recorded on each square.

Habitat Use

Land classifications for Ireland and possible methods of examining habitat associations of different bat species should be examined in 2007-8.

Climate Change and Irish Bats

This issue has the potential to change the composition and dynamics of the Irish bat fauna within a relatively short timeframe. In order to be able to determine with some accuracy the likely impacts of continuing climate change on Irish bat species, including those species targeted by car-based monitoring, detailed modelling of bat activity and weather data needs to be carried out. While some of this can be carried out within the context of present GLM models, to achieve greater understanding, year-round studies of activity of different species is needed but is beyond the scope of the present car-based bat monitoring project.

ACKNOWLEDGEMENTS

We would like to thank each of the 59 people who devoted long and antisocial hours to map and survey routes throughout the country.

Tina Aughney
Ted Barker
Chris Barron
Eileen Biggane
Sinéad Biggane
Emma Boston
Patricia Boston
Shaun Boyle
Donna Cassidy
Damian Clark
Jimi Conroy
Joe Costelloe
Kerry Crawford
Denis Crinigan
Sarah Crinigan
Miriam Crowley
Reggie Cunningham
Guy Dalton
Paschal Dower
Emma Glanville
Clare Heardman
Austin Hopkirk
Rebecca Jeffrey
Conor Kelleher
Ger Kelleher
James Kilroy
Annette Lynch
Deirdre Lynn
David Lyons
Bella Lysaght
Liam Lysaght
Pauli Lysaght
Seppie Lysaght
Ferdia Marnell
Kate McAney
Eddie McCourt
Lee McDaid
Barbara McInerney
Ken Moore
Enda Mullen
Irene O'Brien
Aonghus O'Donaill
Jim O'Donoghue
Sylvia O'Hehir
Dennis O'Higgins
Ciarán O'Keeffe
Una Patterson
Chris Peppiatt
Elaine O'Riordáin
Tim Roderick
Gráinne Roche
Niamh Roche
Lorcan Scott
Lorna Somerville
Dave Tierney
Alyn Walsh
Gemma Weir
Chris Wilson
Jane Woodlock

Thanks also to

- Staff of NPWS in particular Naomi Kingston, Deirdre Lynn and Ferdia Marnell.
- Staff of the Environment and Heritage Service in particular John Milburne.
- Liam Lysaght, formerly of The Heritage Council, and Michael Starrett of The Heritage Council.
- Amy Coyte of the BCT.

REFERENCES

Baagoe H.J. (2001). Danish bats (Mammalia: Chiroptera): Atlas and analysis of distribution, occurrence, and abundance. *Steenstrupia* **26**: 1-117.

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

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., 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.

Davidson-Watts I., Walls S. and Jones G. (2006). Differential habitat selection by *Pipistrellus pipistrellus* and *Pipistrellus pygmaeus* identifies distinct conservation needs for cryptic species of echolocating bat. *Biological Conservation.* **133**: 118-127.

Elliott P. (1998) Ultrasonic bat detectors: a beginners' guide. *Journal of Biological Education* 32: 1.

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.

Magris L. (2003). *The Jersey Bat Survey*. Environment and Public Services Committee. Jersey.

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.

Mayer F. and Van Helverson O. (2001). Sympatric distribution of two cryptic bat species across Europe. *Biological Journal of the Linnean Society*, **74:** 365-374.

Oakely S.F. and Jones G. (1998). Habitat around maternity roosts of the 55kHz phonic type of pipistrelle bats (*Pipistrellus pipistrellus*). *Journal of Zoology, London*. **245**: 222-228.

Robinson R.A., Learmonth J.A., Hutson A.M., MacLeod C.D., Sparks T.H., Leech D.L., Pierce G.J., Rehfisch G.J., Crick H.Q.P. (2005). *Climate Change and Migratory Species*. BTO Research Report 414.

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

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

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

Russ J. 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.

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.

Vaughan N., Jones G. and Harris S. (1997). Habitat use by bats (Chiroptera) assessed by means of a broad-band acoustic method. *Journal of Applied Ecology*. **34**: 716-730.

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.

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).

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.

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.l for a two sided test).

APPENDIX I

Methods

Training workshops to explain the project to new surveyors and demonstrate the equipment were carried out in June and July 2006 in Belfast, Dublin, Navan, Killarney, Swinford, Lanesborough and Moyne.

Volunteers/NPWS/EHS staff were presented with an information pack which included 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, guidelines for using a minidisc recorder, and two recording sheets, one to record transect details and one to record survey information. In addition, each surveyor was equipped with maps, a minidisc recorder, a stereo connecting lead, a bat detector (Tranquility Transect), a car window mounting clamp, a thermometer, a first aid kit and a flashing beacon. A training CD was 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.

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

Each surveyor was 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 were recorded by the surveyor on the appropriate form and highlighted on the maps provided.

Each survey square was driven in July 2006. A repeat survey was carried out in mid-August 2005. The bat detector was positioned at 45° to the rear of the car in the horizontal plane and 45° to the vertical plane as previous work had shown that this angle minimised background noise and interference. Surveying began 45 minutes after sunset and volunteers were required to drive at 24kmph along each monitoring transect, recording bat activity via the bat detector onto the minidisk recorder. This low speed was chosen because low speeds reduce background noise and the effect of Doppler shifts on recorded calls (for details see Catto *et al.* 2004).

Sonographic analysis
Time expansion audio data was transferred to the computer hard drive as separate *.wav files representing the numbered tracks (20 files, one for each monitoring transect) on the minidisc using the software Win Nmd (v1.2x, Christian Klukas). Occasionally, multiple tracks were recorded for each monitoring transect and these were joined into a single *.wav file using the software program AddAWav (v1.5, Geoff Phillips). Using Bat Sound

(Pettersson Elektronik AB) software, bats were categorised into species from the measured parameters of their echolocation calls.

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

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

A minor change was made to the methodology used in 2005, whereby the second year of the study (2004) was taken as the base year (i.e. the year given the index value 100.0), rather than the first year.

APPENDIX II

Results

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 A.1: 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
All years	3589	2194	1.64	53.6	169251	3481	2.06	4.01

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
All years	1374	2194	0.63	32.5	169251	1350	0.80	1.49

c) 50khz pips

		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
All years	645	2021	0.32	21.9	156026	644	0.41	0.78

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
All years	82	2194	0.04	2.9	169251	82	0.05	0.09

e) Leisler's bat

		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
All years	1448	2214	0.65	23.9	170796	1428	0.84	1.62

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
All years	30	2214	0.01	0.9	170796	29	0.02	0.03

Trends
As in 2005, Generalised Linear Models with a Poisson error distribution were fitted, but using bootstrapping at the square level to generate confidence limits. The number of passes per survey were modelled, using the log of total number of 0.32s recordings per survey as a covariate, which effectively does something very similar to analysing the passes per minute, but allows use of a Poisson error distribution. The graphs below mean passes per survey, adjusted to allow for the differing numbers of 0.32s recordings.

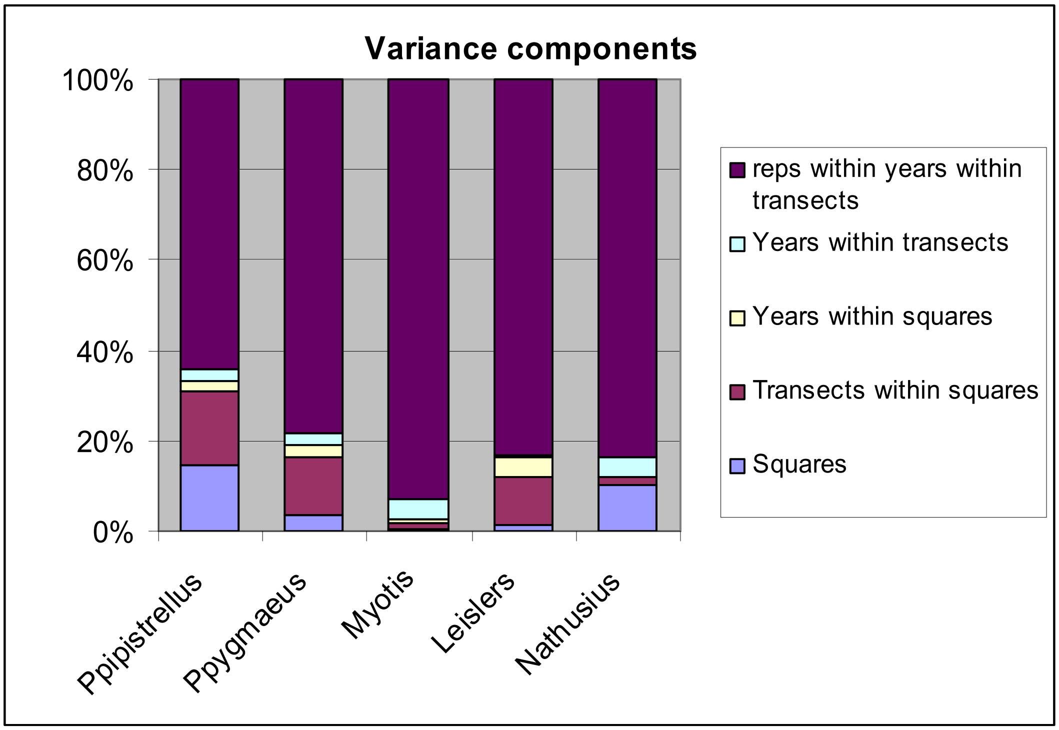
Since the annual estimates depend on the other factors in the model their values will change somewhat from year to year. Thus, for example, last year's estimate for the 2003 value for common pips was 19.4, whereas this year it is estimated to be 19.9 passes per survey; this is due to new information from the 2006 data on the relative magnitudes of the site effects and the relationship with number of recording periods. To minimise these changes in the future, the value of 0.32ms recording periods used for the estimates have been standardised; all annual means are now predicted as if all squares had a total of 1,500 0.32s periods (i.e. 75 periods per mile transect). However, there will still be some minor changes in the future as a result of changes in the estimates for the sites (i.e. 30km squares).

Graphs of trends for each species are shown in the main report.

REML models

Last year, the REML models were largely used as a basis for power analysis. This year they are not needed for that purpose, but they are still worth doing to get an idea of the important sources of variation and to examine the effect of some variables of interest. Figure A.1 shows the relative magnitudes of the variance components. As is usually the case with bat survey data, the biggest source of variation is generally the lowest level of random variation (in this case reps within years within transects). Interestingly, for all species except Nathusius' pipistrelle (where there is insufficient data for results to be reliable) there is more variation at the level of the 1 mile transects than at the 30km squares, perhaps suggesting that factors such as local habitat are more important than wider geographic differences.

Figure A.1: relative sizes of variance components from a REML model.


Variance components
100%
80%
60%
40%
20%
0%
Ppipistrellus
Ppygmaeus
Myotis
Leislers
Nathusius
reps within years within transects
Years within transects
Years within squares
Transects within squares
Squares

APPENDIX III: Other Wildlife

Square-Survey	Dog	Cat	Rabbit	Deer (red)	Deer (sika)	Fox	Rat	Mouse	Badg-er	Hare	Hedge-hog	Crow	Frog	Vole	Shrew	Unid Small Mamm-al	Long-eared owl	Stoat
G20 -1		2																
G20 - 2	3	1				1			1									
G89 - 1		6		4						1								
G89 - 2		5	2	2				1							1	1		
H13 - 1		13	3															
H13 - 2	2	13				1		2										
H40 - 1		2																
H40 - 2		2	1															
H79 - 1		6	1			(1)	(1)						1					
J06 - 1		4	2															
J06 - 2	2	3	2															
L64 - 1								1										
L64 - 2		4																
M24 - 1		7				3		1										
M24 - 2		3									1 (1)							
M87 - 1	1	3	(1)						(1)									
M87 - 2		7	(2)			2 (1)								(1)				
N11 - 1						1	2				1							
N11 - 2						1	1		1							1		
N74 - 2	1	5	3			3	(2)	1			(1)							
N77 - 1	2	11	1 (1)			1			1 (2)			(1)						
N77 - 2		6 (1)	1				1						3					
O04 - 1		7					(1)											
O04 - 2																		
R22 - 1		1	2			1				2								
R22 - 2		1	3			1			1									
R28 - 1	1	1				1			5									
R28 - 2	2	3				1		1	1									
R88 - 1	8	6				1			1									
R88 - 2	3	4						1	(1)									

Square-Survey	Dog	Cat	Rabbit	Deer (red)	Deer (sika)	Fox	Rat	Mouse	Badg-er	Hare	Hedge-hog	Crow	Frog	Vole	Shrew	Unid Small Mamm-al	Long-eared owl	Stoat
S12 - 1		2				1	(1)				3							
S12 - 2	1	2	2					(1)										
S15 - 1			1					1										
S78 - 1	5	4	3		1 (1)	1												
S78 - 2		5	6		1	1	1	1										
T05 - 1		4	1 (1)			1	1					(1)					1	
T05 - 2		1	2															
V93 - 1																		
V93 - 2		(1)	(1)								1							
V96 - 1																		
V96 - 2		3 (1)		1		1												
V99 - 1	1	1				2			1									1
V99 - 2	7	2					1	1										
W56 - 2		5				1					1							
X49 - 1		2	(1)			1		2										
X49 - 2										1								
Total Alive	**39**	**157**	**36**	**7**	**4**	**27**	**7**	**13**	**12**	**4**	**7**	**0**	**4**	**0**	**1**	**2**	**1**	**1**
Total Dead	**0**	**3**	**7**	**0**	**1**	**2**	**5**	**1**	**4**	**0**	**2**	**2**	**0**	**1**	**0**	**0**	**0**	**0**