Bat Conservation Ireland

Irish Bat Monitoring Schemes

Annual Report for 2009

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

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1.0 Executive Summary

This annual report provides information on Bat Conservation Ireland's monitoring schemes:

● Car-Based Bat Monitoring Scheme (All Ireland)
● All Ireland Daubenton's Bat Waterway Monitoring Scheme
● Brown long-eared Roost Monitoring Scheme for the Republic of Ireland

Despite poor weather conditions prevailing through much of the 2009 survey season, a considerable body of bat survey work was completed. Training courses were held at 14 locations as part of the All Ireland Daubenton's Bat Waterway Monitoring Scheme and at two locations for Car-Based Bat Monitoring.

For the Car-Based Bat Monitoring Scheme 70 individuals participated in surveys of 28 squares around the island. Overall bat encounter rates for this survey were lower than in 2008, particularly for common pipistrelles and Leisler's bat. The soprano pipistrelle remained at roughly similar levels to 2008. This year, for the first time, GAM models of smoothed trends over time have been applied to car-based bat monitoring data. These models reveal a similar, quadratic trend among common pipistrelles and Leisler's bat, with increases in both in the initial years of the survey, followed by a decline since 2007. The soprano pipistrelle appears to be on a more stable or slightly increasing trajectory. While Nathusius' pipistrelle numbers declined in 2008, 2009 saw an increase in encounter rates with this species. The Nathusius' pipistrelle, brown long-eared bats and *Myotis* spp. are still, however, encountered in very small numbers by this scheme, so any attempt to investigate trends in these species' populations is confounded by very wide error bars.

In total, 336 living vertebrates other than bats were observed by car-based bat monitoring surveyors in 2009; 56% of these were cats. Rabbits were second most frequent at 12%, and foxes came third accounting for 10% of records. Cats had shown an increase in encounter rates from 2006 to 2008 but observations (per hour) of this species were lower in 2009.

In 2009, 185 volunteer teams participated in the All Ireland Daubenton's Bat Waterway Monitoring Scheme. In total, 209 waterway sites were surveyed in all 32 counties. Of these 209 sites, 169 were surveyed twice. This constitutes the highest number of completed surveys in any year to-date. Over 16,500 'Sure' Daubenton's bat passes were recorded on 186 waterway sites (89%). This year, for the first time, BCIreland carried out a mapping exercise with Daubenton's presence/absence data. This mapping can be carried out on an individual site, river, catchment or county level. Possible uses for such representation of the data are discussed. REML analysis showed that several factors influence Daubenton's activity along waterways, such as daily rainfall, waterway width, air temperature and start time of the survey. Daubenton's bat numbers showed evidence for a decline from 2006 to 2008 but in 2009 numbers appeared to have recovered a little. This year, a Binomial GAM (smoothed trend line) was also used to plot yearly data and this method is proposed for future assessments of Daubenton's bat trends.

For Brown Long-eared Roost Monitoring, 45 volunteers participated in 2009. Volunteers provided count data for 16 roost sites. In total, 75 monitoring surveys were carried at 38 roosts. In addition, 30 roosts were assessed in 2009 but deemed unsuitable for inclusion in the yearly monitoring scheme. Using the highest results for each roost monitored in 2009, the total number of brown long-eared bats counted was 1,075 individuals. Power analysis indicates that the current target of 30-50 roosts should provide robust data to determine red or amber alert declines, or 50% increases in brown-long eared bat populations. So far, there are too few years of data available to determine trends in brown long-eared bat populations. Recommendations are made for optimising training and field work in 2010, the final year of the current brown long-eared bat, in order to ensure a cost-effective robust scheme can be proposed for long-term monitoring of the species.

2.0 GENERAL INTRODUCTION

2.1 Why Monitor Ireland's Bats?

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

Irish bats are protected under domestic and EU legislation. Under the Republic of Ireland'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 similarly 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 lists various species that require strict protection. Article 11 of the Habitats Directive requires member states to monitor all species listed in the Habitats Directive and Article 17 requires States to report to the EU on the findings of monitoring schemes.

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

Whilde (1993), in the Irish Red Data Book of vertebrates, listed most Irish populations of bats (those species that were known to occur in Ireland at the time of publication) as Internationally Important. The Red Data List for Mammals in Ireland has been recently updated (Marnell *et al*., 2009) and most of the bat species, including common pipistrelle (*Pipistrellus pipistrellus*), soprano pipistrelle (*P. pygmaeus*), Daubenton's bat (*Myotis daubentonii*) and brown long-eared bat (*Plecotus auritus*) are currently considered of Least Concern. All of these species are monitored using one of the BCIreland monitoring schemes. One of the species included in BCIreland's monitoring, the Leisler's bat (*Nyctalus leisleri*), is, however, considered Near Threatened. It has been assigned this threat status because Ireland is considered a world stronghold for the species (Mitchell-Jones *et al*., 1999). The status of the European Leisler's bat population is Least Concern (Temple and Terry 2007). This species is still, however, infrequent in the rest of Europe compared with Ireland where it is quite common.

2.2 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. In addition, the data should also be able to pinpoint population increases should these occur (for more details on Power analysis for Car-Based Bat Monitoring see Roche *et al.*, 2009 and for the Daubenton's Waterways Survey see Aughney *et al.,* 2009).

2.3 The Monitoring Schemes

Despite high levels of legal protection for all species, until 2003 there was no systematic monitoring of any species apart from the lesser horseshoe bat in Ireland. To redress this imbalance The Car-Based Bat Monitoring Scheme was first piloted in 2003 and targets the two most abundant pipistrelle species (common and soprano pipistrelles) and the Leisler's bat (Catto *et al.*, 2004). These species are relatively easy to detect and distinguish from each other on the basis of echolocation calls. The car based survey makes use of a broadband bat detector which picks up a range of ultrasound which can be recorded in the field and analysed post-survey. This method therefore allows survey work to be carried out by individuals with little or no experience in bat identification since identification is completed post survey work.

The car-based monitoring scheme was followed in 2006 by the All Ireland Daubenton's Bat Waterways Monitoring Scheme (e.g. Aughney *et al.,* 2007). This scheme follows a survey methodology devised by the Bat Conservation Trust (BCT UK). Narrow band, heterodyne detectors are used so volunteers who conduct the survey are trained in the identification of the Daubenton's bat prior to field work. Surveyors count the number 'bat passes' of this bat species for 4 minutes at each of the ten fixed points on linear waterways. The onset of this scheme was a very significant development in bat monitoring here since it represented the first large-scale recruitment of members of the Irish public to bat conservation-related work.

More recently, in 2007, a brown long-eared bat monitoring scheme was piloted and is continuing for a 3-year monitoring period (Aughney and Roche, 2008). This project concentrates on counts of brown long-eared bats at their roosts and is conducted by individuals with a greater level of experience in bat identification than is necessary for the Daubenton's or car-based surveys. This survey protocol involves at least two counts per annum (May to September) using three potential survey methods depending on the structure, access and location of bats within, and emerging from, the roost.

The Car-Based Bat Monitoring Scheme and All Ireland Daubenton's Bat Waterway surveys are all-Ireland schemes. The brown long-eared roost monitoring has, so far, been based in the Republic of Ireland. Regular monitoring under BCIreland management is, therefore, in process for five of the Annex IV bat species for the Republic of Ireland, and for four species in Northern Ireland. Additional BCT UK Field Surveys are also undertaken in Northern Ireland. Data collected from those surveys feed into the BCT's UK reporting mechanisms.

2.4 Weather in Summer 2009

During the early part of the season, when initial brown long-eared bat roost counts were carried out, much of the weather was unsettled. In May, rain or showers were recorded on many days. This rain was accompanied by unusually strong winds for May at times, particularly during the first week. There were also short spells of dry and sunny weather, especially at the end of the month, when temperatures rose well above normal. May rainfall totals were above normal at all stations except in parts of the east and southeast. Mean air temperatures for the month overall were above normal everywhere, by close to one degree generally.

In June, there were warm and sunny conditions at times, but also spells of cool and unsettled weather, producing occasional heavy rain. Very warm weather was recorded at the beginning and end of the month and this brought mean monthly air temperatures above normal everywhere, especially in western and south-western areas. Mean monthly values were between one and two degrees above normal generally. It was the warmest June since 1970 at a number of stations. Temperatures fell significantly during the second week though; after reaching around 25°C at the start of the month. Mean windspeeds for June were below normal everywhere.

Later in the summer, in July and August when the Car-Based Bat Monitoring and Daubenton's surveys were also being carried out, rainfall totals were above normal everywhere for the third successive summer, with around twice the average rainfall at some stations.

In July, apart from a short spell of dry weather between the 7th and 9th, rain or showers were recorded on each day during the month, resulting in record high monthly totals at some stations. The weather pattern of the previous two summers was repeated, with Atlantic depressions tracking over or close to Ireland, producing substantial falls of rain at times, with frequent thunderstorms. The north and northwest of the country fared relatively well in July, however; in these areas the lowest rainfall totals were recorded and both mean temperatures and sunshine amounts were well above normal.

After the wettest July for over 50 years in places, August was another month of very unsettled weather, with rainfall totals well above normal in western and south-western areas. There was very little variation in the weather pattern throughout August: areas of low pressure passing close to Ireland's north coast brought a succession of Atlantic frontal systems, giving some significant falls of rain and localised flooding at times. These conditions also gave a mild and cloudy month, but with daytime temperatures only rarely rising above 20°C.

While temperatures rose above 20°C on relatively few days during July and August, minimum temperatures were above normal throughout almost all of the summer.

Mean windspeeds for the summer season (June, July and August) of between 6 and 12 knots *(11 to 22km/h)* were above normal everywhere and were the highest for summer for up to 35 years at Shannon Airport.

The Poulter index is a method of rating the summer weather (June to August), using a formula based on mean temperature, rainfall and sunshine for each station, i.e. the higher the index, the 'better' the summer weather. This summer, the index at Valentia Observatory was well below normal (its lowest since summer 1985), but it was well above normal at Malin Head, while at other long-term stations of Dublin (Phoenix Park) and Birr it was close to average.

The unsettled weather of July and August extended into the first week of September but high pressure led to settled conditions from the 9th onwards. Sunny conditions were recorded up to the middle of the month but afterwards the weather remained dull. Rainfall totals were below normal and temperatures were a little above normal generally.

The high summer rainfall had less direct negative impact on Daubenton's and car-based surveys in 2009 compared with 2008, when many surveys could not be completed due to flooded rivers, flooded roads or rain showers. In 2009 just one car-based survey was not completed due to poor weather, although a number of car-based surveyors recorded one or more pauses while surveying to allow light rain showers to pass. For the Daubenton's survey 10 survey teams failed to complete surveys due to flooded riverbanks and dangerously high flood waters in 2009. The poor weather had little impact on internal counts at brown long-eared bat roosts. However, a number of emergence count surveys at brown long-eared bat roosts were cancelled or interrupted by sudden rain showers.

All weather data derived from www.meteireann.ie.

3.0 CAR-BASED BAT MONITORING

3.1 Methods

Training of surveyors is carried out in June and early July each year. Survey teams are provided with all equipment needed for the survey including: a time expansion bat detector (Courtpan Electronic, Tranquility Transect), minidisc recorder and minidiscs, pre-stamped envelopes to return the minidiscs, instruction manuals, recording sheets, batteries, flashing beacon, thermometer and a first aid kit.

Each year survey teams complete surveys of a mapped route within a defined 30km Survey Square. Routes covered 20 x 1.609km (1 mile) Monitoring Transects each separated by a minimum distance of 3.2km (2 miles). However, resulting in concerns for driver safety and following an analysis of its likely impact on the power of the data (see Roche *et al.*, 2009), in 2009 surveyors were asked to omit the final five transects from their survey route resulting in 15, 1.6km transects being surveyed.

Surveyors are asked to undertake the survey on two dates, one in mid to late July (Survey 1, S1) and one in early to mid-August (Survey 2, S2). Transect coverage begins 45 minutes after sundown. Each of the 1.609km transects is driven at 24km (15 miles) per hour (at night) while continuously recording from the time expansion bat detector (set to x10 time expansion) on to minidisc.

On completion of surveys, minidiscs are forwarded to BCIreland for analysis. Each track is downloaded to Bat Sound™ and calls are identified to species level where possible. Species that can be identified accurately using this method are the common pipistrelle, soprano pipistrelle, and Nathusius' pipistrelle (*Pipistrellus nathusii*). Pipistrelle calls with a peak in echolocation between 48kHz and 52kHz are recorded as 'Pipistrelle unknown' because they could be either common or soprano pipistrelles. Leisler's bat, a low frequency echolocating species, can also be easily identified using this method. Occasional calls of *Myotis* bats are recorded but these are noted as *Myotis* spp. since they could belong to one of a number of similar species – Daubenton's, whiskered, Natterer's or Brandt's bat (*Myotis daubentonii, M. mystacinus, M. nattereri, and M. brandtii*). Occasional social calls of brown long-eared bats are also recorded.

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

3.1.1 Statistical Analysis

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

This year, the analysis has been carried out using the first 15 x 1.6km transects only, from 2003-2008, so that results are comparable with the reduced 2009 sampling plan. All annual estimates are now predicted as if each survey had a total of 1,125 0.32s recording intervals or snapshots (i.e. 75 snapshots for each of the 15 x 1.6km transects).

Generalised Additive Models (GAMs) have been fitted to the annual means to give a visual impression of the trend over time. This is the first year that we have applied curved trend lines to the data.

REML (Residual or Restricted Maximum Likelihood) models were applied to log transformed bat count data and climate variables (temperature and rainfall totals) to determine if there were any significant relationships between bat activity and these weather variables. In most cases bat count data from both surveys in a square in a year were included so results therefore compare both within square differences (e.g. more bats present on warmer nights) and between square differences (e.g. more bats present in warmer squares).

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.

3.2 Results

Thirteen individuals attended two training courses in Belfast and Wexford in 2009.

Survey work in 2009 was carried out from mid-July to the beginning of August and a repeat survey was carried out in early to mid-August. The median date of the first survey in 2009 was 23/7/07. The median date of the second survey was 12/8/08.

All 28 squares were surveyed in 2009. Repeat surveys were carried out in 27 of these, see Figure 3.1. In total 1290km of monitoring transects were driven and approximately 350hrs of survey time was spent on the scheme by 70 volunteers. Limited or no data were available from transects on four survey routes, mainly due to equipment problems, although poor weather also hindered completion of one survey in 2009. Overall, the quality of data collected in 2009 was very good. Full datasets were available from 27 routes in July and 25 routes in August, all of which were repeat surveys. Squares that were surveyed in 2009 cover the length and breadth of the island with squares in the extreme north, west, south and east of the island included, along with a good spread of squares in the midlands.

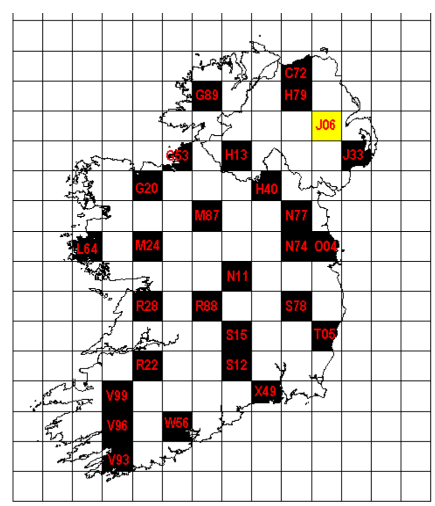


Figure 3.1: Location of 30km Survey Squares.

Black squares were surveyed twice in 2009, Yellow squares were surveyed once.

Note that, not all surveys were completed due to equipment problems or poor weather conditions.

In total, 2147 bat encounters were recorded during the July and August 2009 surveys, from 787 independent monitoring transects. An overall lower number of encounters in 2009 compared with 2008 can in part be explained by the reduced (15 transect) survey length in 2009.

Encounter rates with the various bat species, however, (not corrected for the time spent surveying, or to allow for different distributions of survey squares in earlier years of the survey), showed a decrease in Leisler's bats and common pipistrelles compared with 2008 results. Soprano pipistrelle encounter rates were slightly lower than 2008 (see Table 3.1). The proportions of species encountered (Figure 3.2) show a roughly similar picture to previous years with common pipistrelles the most abundant species accounting for almost half of all bat encounters. Soprano pipistrelles and Leisler's bats account for 26% and 18% of total bat encounters, respectively, in 2009. Eight percent of all encounters are pipistrelles that could be either soprano or common. Nathusius' pipistrelles, *Myotis* species and brown long-eared bats were encountered in very low numbers.

Table 3.1: Raw bat encounter data, per 1.609km/1 mile transect, not corrected to encounters per km or per hour, Car-Based Bat Monitoring Scheme 2003-2009. Average number of bats reflects the average number of bat encounters observed during each 1.609km/1 mile transect travelled. Total Number of Transects (n): 2003 n=180; 2004 n=577 for pipistrelle, *Myotis* spp. and total bats, n=597 for Leislers; 2005 n=608; 2006 n=887; 2007 n=889; 2008 n=927, 2009 n=787 for all species. Note that the detector records for just 1/11th of the time spent surveying so to determine the actual number of bat encounters per km this must be divided by 0.146 (the total distance sampled for each 1.609km transect).

Average encounters per 1.6km transect	Common pipistrelle	Soprano pipistrelle	Pipistrelle unidentified	Nathusius' pipistrelle	Leisler's bat	Myotis spp.	Brown long-eared	Total Bats
2003	1.294	0.478	N/a	0.000	0.289	0.039	n/a	2.100
2004	1.905	0.695	0.443	0.000	0.511	0.050	n/a	3.621
2005	1.344	0.574	0.266	0.001	0.544	0.035	n/a	2.781
2006	1.701	0.652	0.271	0.033	0.892	0.029	0.024	3.620
2007	1.77	0.639	0.253	0.015	0.631	0.036	0.019	3.390
2008	1.686	0.768	0.294	0.006	0.739	0.029	0.002	3.537
2009	1.212	0.714	0.221	0.032	0.492	0.032	0.011	2.728
Minimum in 2009	0	0	0	0	0	0	0	0
Maximum in 2009	48	45	21	14	30	4	2	94
Standard Dev. 2009	±11.1	±10.6	±3.83	±2.006	±7.4	±0.912	0.47	±22.26
TOTAL ENCOUNTERS 2009	**954**	**562**	**174**	**25**	**387**	**25**	**9**	**2147**

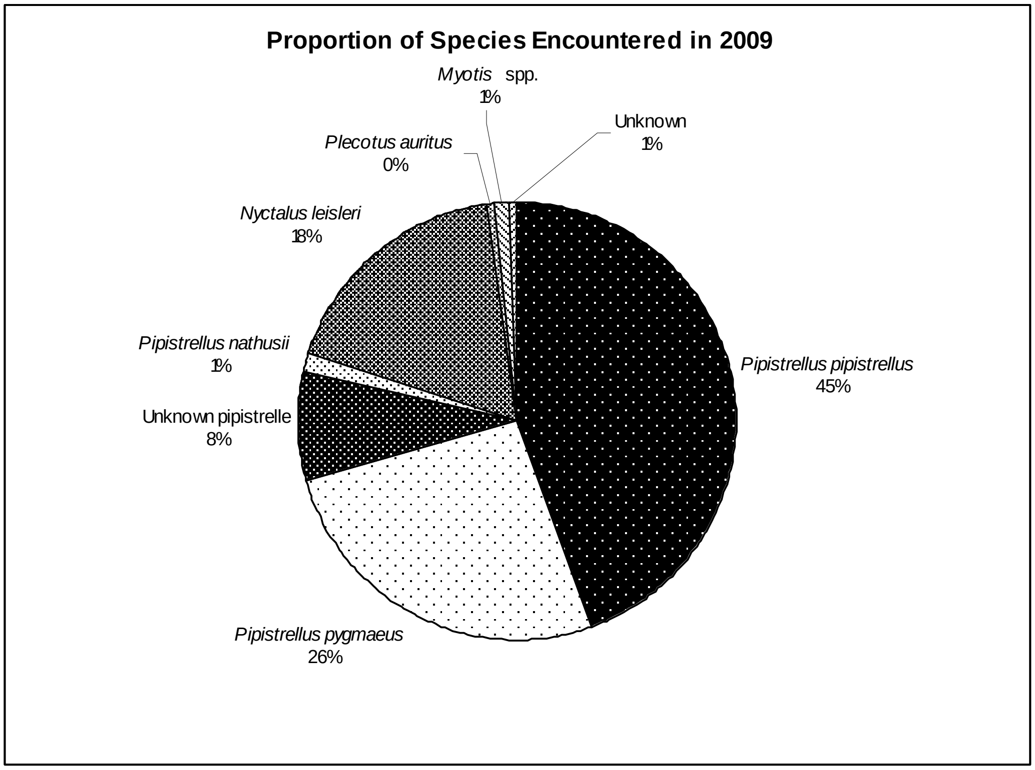


Figure 3.2: Proportion of species encountered during the survey in 2009. Total number of bat encounters, 2147. Excepting social calls of Leisler's bats and brown long-eared bats, which are unlikely to be mistaken for those of other species, bat social calls were noted during sonogram analysis but are not included in the above pie chart or in any statistical analyses.

Overall encounter rates varied between squares and between surveys, however, in general the squares with highest encounter rates were found in the east and south of the country. These included squares S78 and V93, both of which averaged over 83 bat encounters per km. R28, located in Clare, was also one of the highest encounter rate squares in 2009. Encounter rates per hour for each survey in each square are shown in Appendix 1, Tables A1.1 and A1.2 with the overall average shown in Table 3.2 below.

Table 3.2: Average number of bat encounters per hour for all surveys, 2009. Ppip = *Pipistrellus pipistrellus*, Ppyp = *Pipistrellus pygmaeus*, Pipun = Unidentified pipistrelle echolocating between 48 and 52kHz, Pnath = *Pipistrellus nathusii*, Nl = *Nyctalus leisleri*, Myotis = *Myotis* spp., BLE = *Plecotus auritus*, 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 hour.

All Surveys 2009	**Ppip/hr**	**Ppyg/hr**	**Pipun/hr**	**Pnath/hr**	**Nleis/hr**	**Myotis/hr**	**BLE/hr**	**Total/hr**
Overall Mean	18.99	10.70	3.29	0.49	7.58	0.46	0.19	41.91
Standard Deviation	12.04	10.03	3.54	1.99	7.67	0.87	0.53	21.31
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.16
Maximum	53.13	40.95	17.28	13.86	32.27	3.29	2.42	92.98

3.2.1 Common pipistrelles,
Pipistrellus pipistrellus

3.2.1.1 2009 Results

The overall average number of *Pipistrellus pipistrellus* encounters per hour was 20.4 during Survey 1 in 2009 and 17.5 in Survey 2. The overall average number of common pipistrelle encounters per hour for both sampling periods was 18.99 (see Table 3.3). This is lower than the overall average of 25.87 in 2008, 27.31 in 2007 and 25.8 in 2006.

Common pipistrelles were the most frequently encountered species during the monitoring scheme in 2009 and in all survey years to-date. Figure 3.3 illustrates low, medium and high encounter rate squares for common pipistrelles in 2009. As in previous years this map shows lower common pipistrelle encounter rates further north and north-west, squares with highest encounter rates are located in the south and east of the country. No common pipistrelles were recorded from square L64, Connemara, as in previous years.

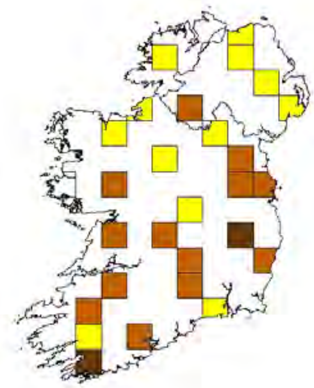


Figure 3.3: Survey squares colour coded according to common pipistrelle encounter rates (per hour) in 2009. The overall average rate of common pipistrelle encounters for all squares in 2009 was 18.99hr^{-1}.

Absent.
Encounter rate $>0\leq20hr^{-1}$
Encounter rate $>20\leq40hr^{-1}$
Encounter rate $>40hr^{-1}$

3.2.1.2 Trends

Figure 3.4 shows the results of a Generalised Linear Model applied to the car-based bat monitoring data for the common pipistrelle, along with Generalised Additive Model smoothed curves. It appears to show a quadratic trend, with common pipistrelles increasing in the first few years of the survey to 2007 and then starting to fall.

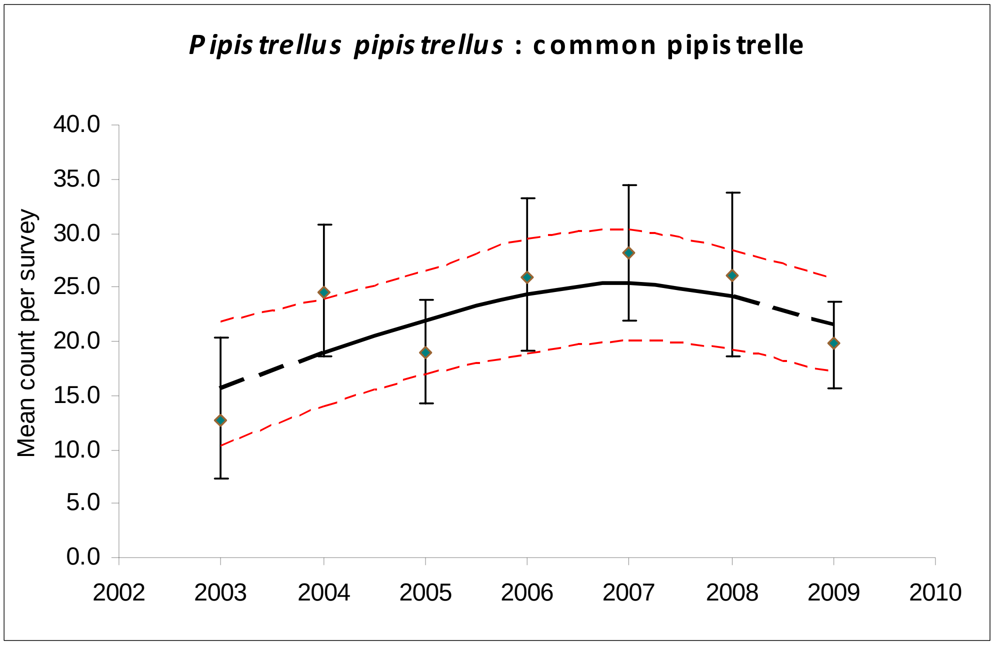


Figure 3.4: Results of the GAM/GLM model for common pipistrelle passes per survey. Green points are estimated annual means derived from the Generalised Linear Model and the bars are 95% bootstrapped confidence limits. The black line is the fitted Generalised Additive Model curve with 95% confidence limits shown by the red dotted lines. All estimates are adjusted to 1,125 0.32s snapshots. Start and end of the smoothed trend are shown with a broken line to illustrate uncertainty at the start of the survey and, for 2008-2009, the possibility that the slope will change with coming years' data.

3.2.1.3 Factors Influencing Common Pipistrelles

A REML model of common pipistrelle passes (logged) with average monthly temperatures for July and August, with rainfall held constant, did not show a significant relationship between the two (Estimate 0.02503, S.E. 0.01684, Wald p-value 0.137). Likewise no significant relationship was found between logged bat passes per minute and monthly rainfall totals (Estimate -0.0005436, S.E. 0.0003537, Wald p-value 0.124), with temperature held constant. It is of interest, however, that the relationship between common pipistrelle passes and mean monthly temperature is positive while the relationship between common pipistrelle passes and total monthly rainfall is negative, albeit very weak.

When temperature data collected by surveyors on the start of each survey was used in a similar model the relationship was also non-significant (Estimate -0.007291, S.E. 0.008237, Wald p-value 0.376).

Since there is sometimes a quadratic relationship between bat activity and temperature, common pipistrelle activity was also fitted with temperature grouped into 2 degree bands. Using this approach, no statistically significant relationship was found.

3.2.2 *Soprano pipistrelles,* Pipistrellus pygmaeus

3.2.2.1 2009 Results

The overall average number of *Pipistrellus pygmaeus* encounters per hour was 10.6 during Survey 1 in 2009 and 10.8 during Survey 2; see Tables A1.1 and A1.2 (Appendix). The overall average number of soprano pipistrelle encounters per hour for both survey periods was 10.7. This compares with an average of 11.78 in 2008 and 10.2 in 2007.

Soprano pipistrelles were the second most frequently encountered species during the monitoring scheme in 2009 and in all survey years to-date, except 2006. Figure 3.5 illustrates low, medium and high encounter rate squares for soprano pipistrelles in 2009. As in previous years trends across the island are more difficult to distinguish than for common pipistrelles although high encounter rate squares are more frequent in western squares. Soprano pipistrelles were recorded in all survey squares in 2009.

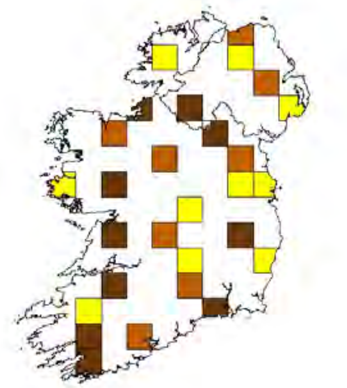


Figure 3.5: Survey squares colour coded according to soprano pipistrelle encounter rates (per hour) in 2009. The overall average rate of common pipistrelle encounters for all squares in 2009 was 10.7hr^{-1}.

(white)	Absent.
(yellow)	Encounter rate >0≤6hr^{-1}
(orange)	Encounter rate >6≤12hr^{-1}
(brown)	Encounter rate >12hr^{-1}

3.2.2.2 Trends

Figure 3.6 shows the results of Generalised Linear Model applied to the car-based bat monitoring data for the soprano pipistrelle, along with Generalised Additive Model smoothed curves. The soprano pipistrelle appears to show quite a consistent, slightly increasing, linear pattern although there is still some evidence for yearly oscillation.

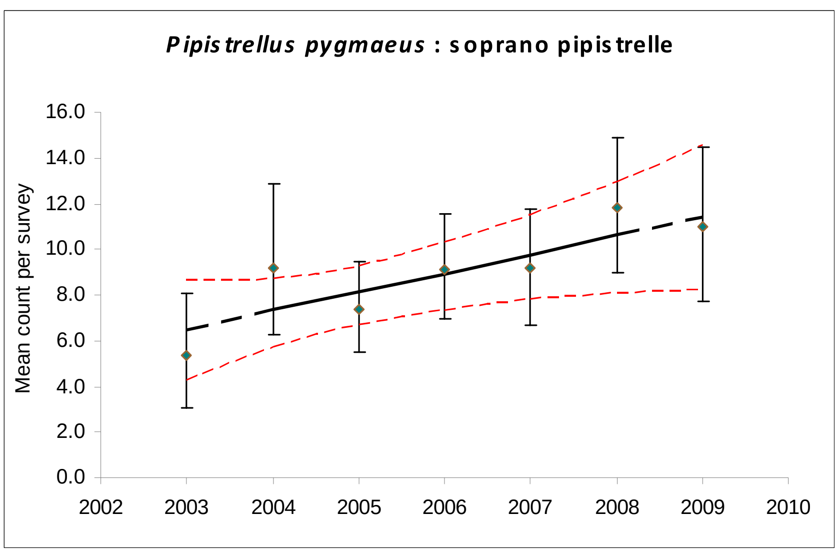


Figure 3.6: Results of the GAM/GLM model for soprano pipistrelle passes per survey. Green points are estimated annual means derived from the Generalized Linear Model and the bars are 95% bootstrapped confidence limits. The black line is the fitted Generalised Additive Model curve with 95% confidence limits shown by the red dotted lines. All estimates are adjusted to 1,125 0.32s snapshots. Start and end of the smoothed trend are shown with a

broken line to illustrate uncertainty at the start of the survey and for 2008-2009 the possibility that the slope will change with coming years' data.

3.2.2.2 Factors Influencing Soprano Pipistrelles

A REML model of soprano pipistrelle passes (logged) with average monthly temperatures for July and August showed a non-significant positive relationship between the two (Estimate 0.02476, S.E. 0.01483, Wald p-value 0.095). No significant relationship was found between logged soprano pipistrelle bat passes per minute and monthly rainfall totals (Estimate -0.0001565, S.E. 0.0003144, Wald p-value 0.619). It is of interest that, like common pipistrelles, the relationship between soprano pipistrelle passes and temperature is positive while the relationship between soprano pipistrelles and rainfall is negative.

However, the REML model accounts for two surveys carried out at the same square every year, and therefore essentially compares between squares (i.e. whether squares with the highest average rainfall have most bats) as well as within square differences (i.e. whether there are more bats when a survey takes place in a wet month). When the within square comparisons are taken out of the model (i.e. just average passes per square per annum are used), the nature of the relationship changes to positive, i.e. more soprano pipistrelles in wetter squares. This relationship is still not significant, however (Estimate 0.00765, S.E. 0.00680, T statistic 1.13, p-value 0.273).

When temperature data collected by surveyors at the start of each survey was used in a REML model the relationship was also non-significant (Estimate 0.006978, S.E. 0.007134, Wald p-value 0.329).

Since there is sometimes a quadratic relationship between bat activity and temperature, soprano pipistrelle activity was also fitted with temperature grouped into 2 degree bands. Using this approach, a close to statistically significant relationship was found (F=2.26 with 4 and 555 d.f., P=0.061), with soprano pipistrelle activity first increasing with average temperature and then falling off above around 18˚C.

3.2.3 Nyctalus leisleri, Leisler's bat

3.2.3.1 2009 Results

The overall average number of *Nyctalus leisleri* encounters per hour was 6.9 during Survey 1 in 2009 and 8.3 during Survey 2, see Tables A1.1 and A1.2 (Appendix). The overall average number of Leisler's bat encounters per hour for both surveys was 7.58. This is lower than the average number of encounters of 11.2 in 2008 and 9.6 in 2007.

Leisler's bat was the third most frequently encountered species during the monitoring scheme in 2009 and in all survey years to-date, except 2006. Figure 3.7 illustrates low, medium and high encounter rate squares for Leisler's bat in 2009. In previous years, high encounter rate squares have been typically most frequent in the south and east of the country, but in 2009 several squares in the north west showed very high Leisler's activity (e.g. G89, M87), while low encounter rate squares were widely distributed, in particular in a band across the southern centre of the island. No Leisler's bats were recorded from square L64, Connemara, although this species has been detected there in the past.

It may be worth noting that unusually high levels of Leisler's bat activity occurred in square G89, Donegal, an area of Ireland highlighted in Met Eireann's climate summaries as having had the least rain and highest temperatures in July 2009.

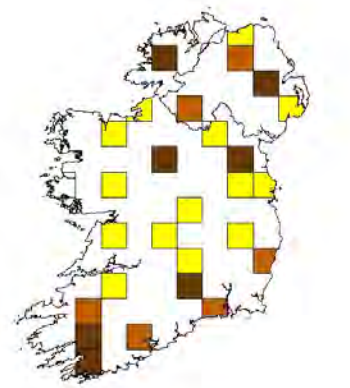


Figure 3.7: Survey squares colour coded according to Leisler's bat encounter rates (per hour) in 2009. The overall average rate of Leisler's encounters for all squares in 2009 was 7.58hr^{-1}.

Absent.
Encounter rate >0≤6hr^{-1}
Encounter rate >6≤12hr^{-1}
Encounter rate >12hr^{-1}

3.2.3.2 Trends

Figure 3.8 shows the results of Generalised Linear Model applied to car-based bat monitoring data for the Leisler's bat, along with Generalised Additive Model smoothed curves. The Leisler's bat appears to show a quadratic trend with an increase in encounter rates to 2007 followed by a decline in 2008 and 2009, similar to that of common pipistrelles. More year-on-year variation about the trend is apparent with Leisler's bat, compared with the common pipistrelle.

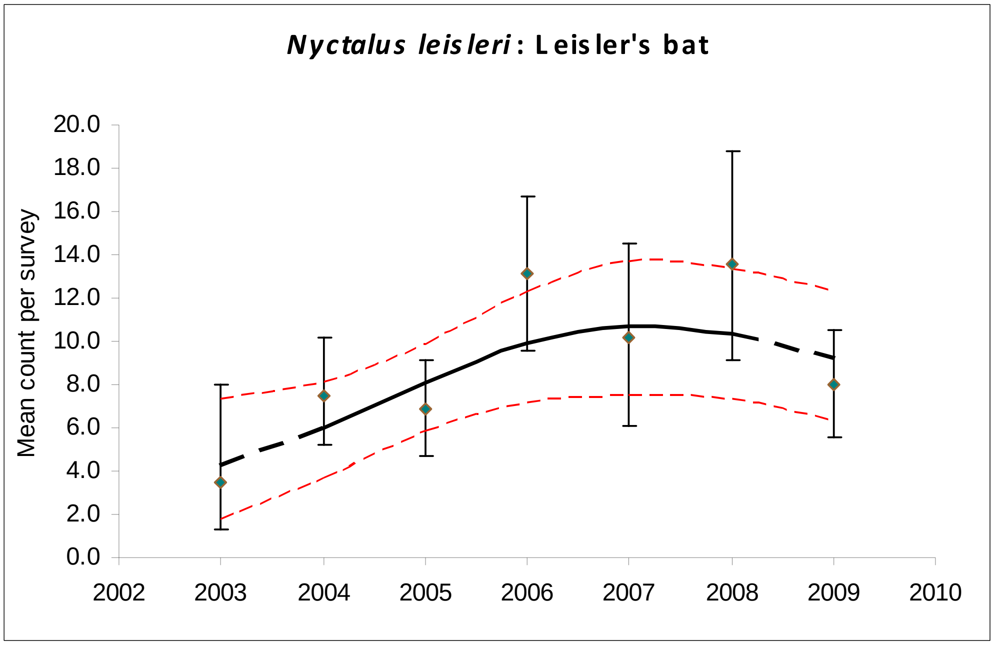


Figure 3.8: Results of the GAM/GLM model for Leisler's bat passes per survey. Green points are estimated annual means derived from the Generalised Linear Model and the bars are 95% bootstrapped confidence limits. The black line is the fitted Generalised Additive Model curve with 95% confidence limits shown by the red dotted lines. All estimates are adjusted to 1,125 0.32s snapshots. Start and end of the smoothed trend are shown with a broken line to illustrate uncertainty at the start of the survey and for 2008-2009 the possibility that the slope will change with coming years' data.

3.2.2.2 Factors Influencing Leisler's Bats

A REML model of Leisler's bat passes (logged) with average monthly temperatures for July and August, and rainfall held constant, showed no significant relationship between the two (Estimate 0.01714, S.E. 0.01400, Wald p-value 0.221). No significant relationship was found between Leisler's bat passes per minute and monthly rainfall totals (Estimate -0.0003532, S.E. 0.0003008, Wald p-value 0.241), with temperature held constant. It is of interest that, like common and soprano pipistrelles, the relationship between Leisler's passes and temperature is positive while the relationship between Leisler's passes and rainfall is negative.

When temperature data collected by surveyors at the start of each survey was used in a similar model the relationship was found, however, to be highly significant (Estimate 0.017436, S.E. 0.006610, Wald p-value 0.009).

Since there is sometimes a quadratic relationship between bat activity and temperature, Leisler's activity was also fitted with temperature grouped into 2 degree bands. Using this approach, no statistically significant relationship was found.

3.2.4 Pipistrellus nathusii, Nathusius' pipistrelle

3.2.4.1 2009 Results

The overall average number of *Pipistrellus nathusii* encounters per hour was low, 0.84 during Survey 1 in 2009 and 0.13 during Survey 2, see Tables A1.1 and A1.2 (Appendix). The overall average number of Nathusius' pipistrelle encounters per hour for both months was 0.49, see Table 3.2. This compares with 0.1 in 2008 and 0.22 in 2007.

Figure 3.9 illustrates squares where the species was present in 2009. This species was encountered for the first time in R88 and H79 in 2009. As in previous years this species was not recorded, during the car-based bat monitoring survey, from squares in the mid-west, e.g. M24, L64, R28 and G20.

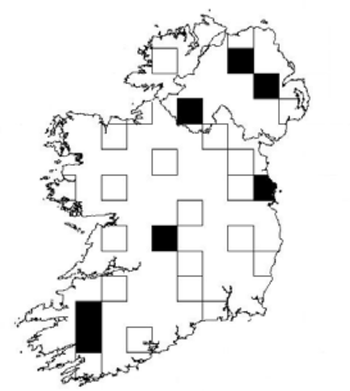


Figure 3.9: Survey squares indicating presence (black) or absence (white) of Nathusius' pipistrelle records from the 2009 car-based bat monitoring scheme.

3.2.4.2 Trends

Nathusius' pipistrelle has clearly increased from the zero values in the first two years of the monitoring scheme, but the encounter rate is too low and error bars too wide to determine trends.

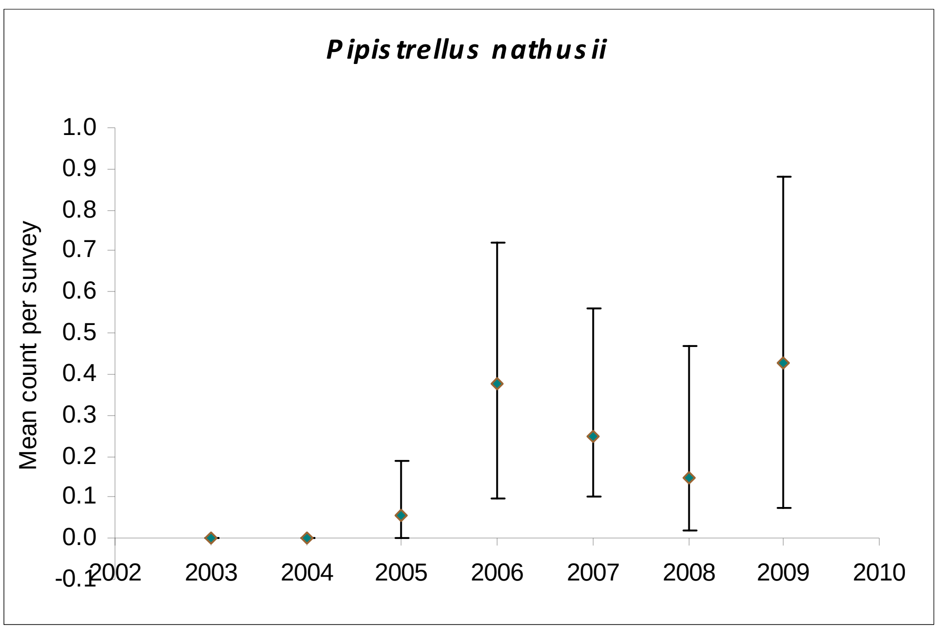


Figure 3.10: Results of the Generalised Linear Model for Nathusius' pipistrelle passes per survey. Green points are estimated annual means derived from the GLM and the bars are 95% bootstrapped confidence limits. Due to poor fit, results of the Generalised Additive Model are not shown. All estimates are adjusted to 1,125 0.32s snapshots.

3.2.5 Myotis spp.

3.2.5.1 2009 Results

The overall average number of *Myotis* species encounters per hour was very low, 0.54 during Survey 1 in 2008 and 0.39 during Survey 2, see Tables A1.1 and A1.2 (Appendix). The overall average number of *Myotis* species encounters per hour for both months was 0.46 in 2009, see Table 3.2. This compares with 0.42 in 2008 and 0.56 in 2007.

Figure 3.11 illustrates squares where this species group was recorded in 2009.

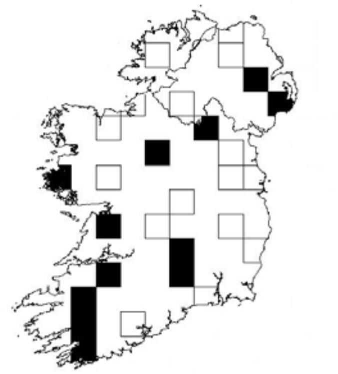


Figure 3.11: Survey squares indicating presence (black) or absence (white) of *Myotis* spp. records from the 2009 car-based bat monitoring scheme.

3.2.5.2 Trends

Myotis spp. numbers seem to show reasonably constant year-year levels (see Figure 3.12), although confidence limits are relatively wide due to the low encounter rate.

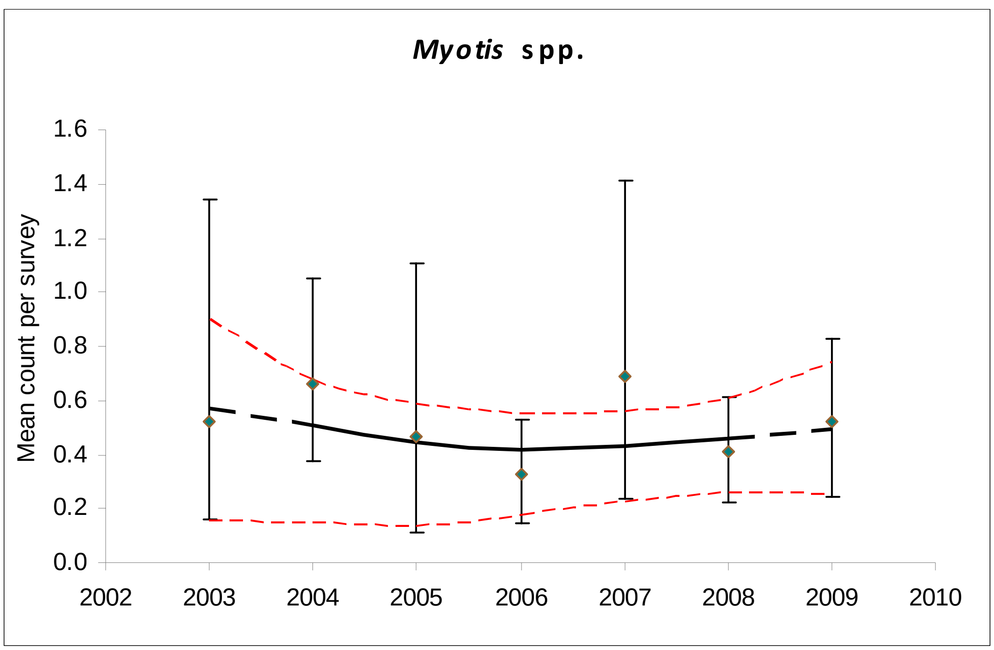


Figure 3.12: Results of the GAM/GLM model for *Myotis* spp. passes per survey. Green points are estimated annual means derived from the Generalised Linear Model and the bars are 95% bootstrapped confidence limits. The black line is the fitted Generalised Additive Model curve with 95% confidence limits shown by the red dotted lines. All estimates are adjusted to 1,125 0.32s snapshots. Start and end of the smoothed trend are shown with a broken line to illustrate uncertainty at the start of the survey and for 2008-2009 the possibility that the slope will change with coming years' data.

3.2.6 Plecotus auritus, Brown long-eared bat.

3.2.6.1 2009 Results

Since this species was encountered just nine times during the survey in 2009, the overall average number of brown long-eared bat encounters per hour was very low, 0.25 during Survey 1 in 2008 and 0.12 during Survey 2, see Tables A1.1 and A1.2 (Appendix). The overall average number of brown long-eared encounters per hour for both months was 0.19 in 2009, see Table 3.2. This compares with 0.03 in 2008 and 0.29 in 2007.

Figure 3.13 illustrates squares where this species was recorded in 2009.

The brown long-eared bat is typically the least commonly encountered species during the monitoring scheme.

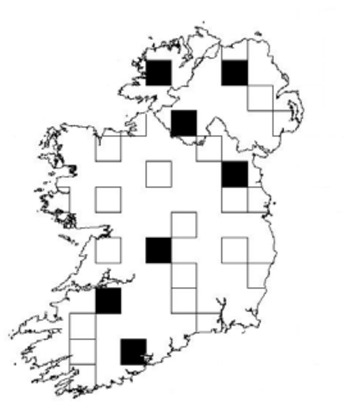


Figure 3.13: Survey squares indicating presence (black) or absence (white) of brown long-eared bat. records from the 2009 car-based bat monitoring scheme.

3.2.6.2 Trends

This species is recorded in very low numbers by the car-based bat monitoring scheme. A dedicated brown long-eared bat monitoring programme, with counts from summer roosts, is now underway. Results from that scheme are shown in Section 5.

3.2.7 Other Vertebrates

As in previous years, surveyors were asked to record living and dead vertebrates, apart from bats, that they encountered during the surveys during and between transects. This resulted in the collection of 336 records of living vertebrates apart from bats and 22 records of dead vertebrates in 2009. Figure 3.14 is a pie chart illustrating proportions of living vertebrate observations attributed to species or species groups. As in previous years, records are dominated by cats, which in 2009 accounted for 56% of all records collected. Rabbits were the second most frequently encountered species with 40 records collected. Foxes were third most common. No stoats or mink were recorded and just one deer was recorded in 2009.

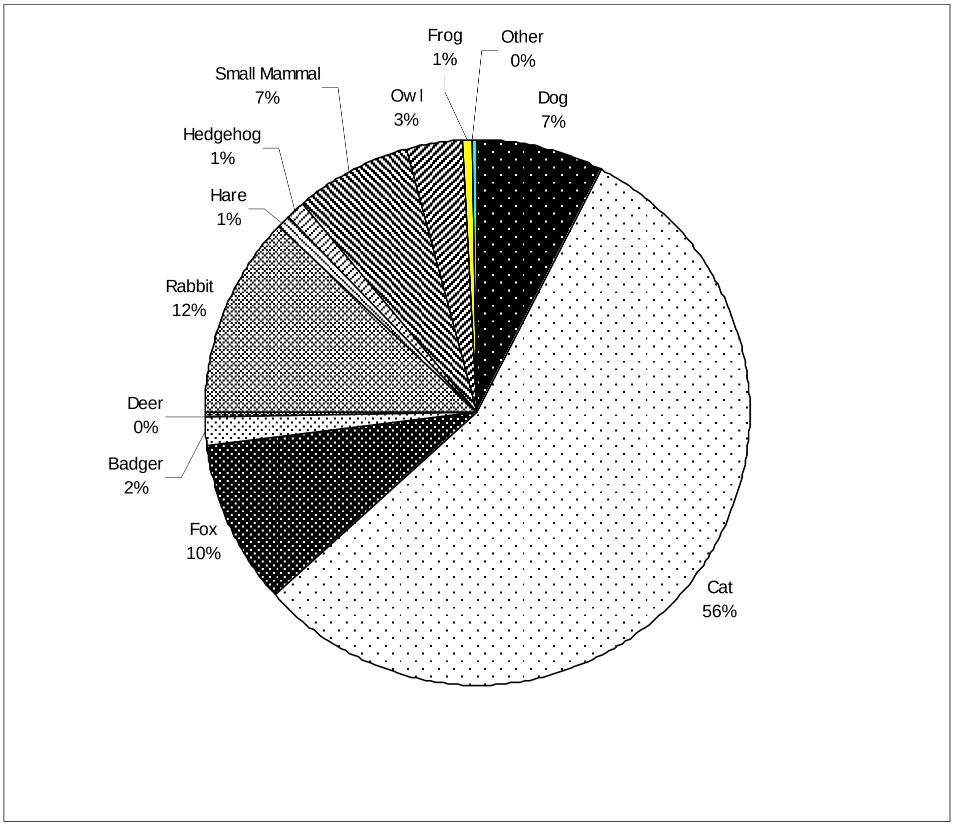


Figure 3.14: Living vertebrates, other than bats, observed during 2009, n=336. The category 'Small mammals' includes mice, rats, shrews, voles and unidentified small mammals. The category 'Owls' includes three Barn Owl, five Long-eared Owl and three unspecified records. The 'Others' category includes one pine marten record for Survey Square S15.

3.2.7.1 Cats

Cats are the other vertebrate species most frequently encountered during the survey. From 2006 until 2008 this species showed a steady increase. In 2009, there was a decline in the number of cats observed per hour of surveying.

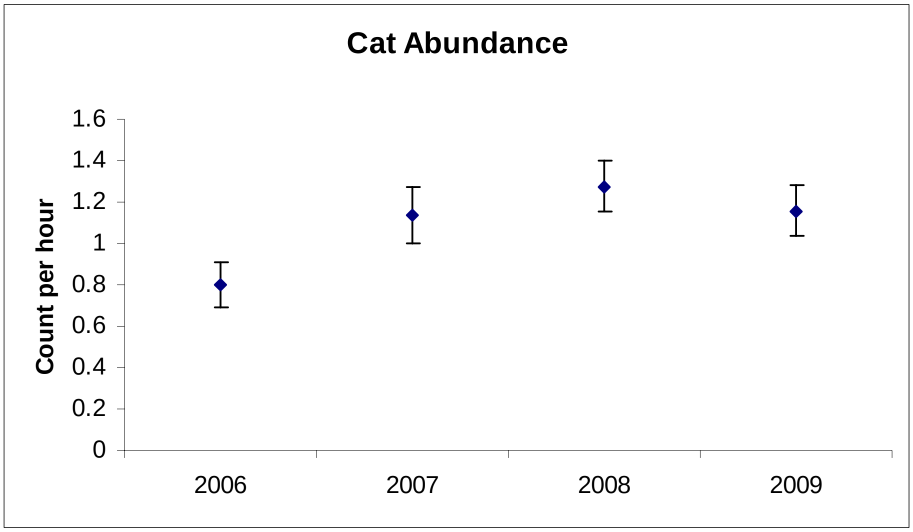


Figure 3.14: Average number of cats observed per hour of surveying with 95% standard error bars.

3.2.7.2 Foxes and Rabbits

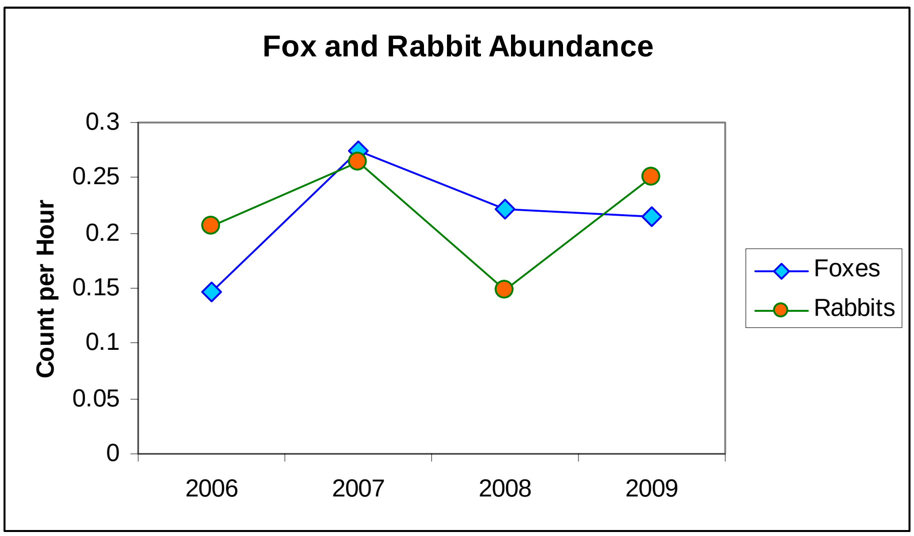


Figure 3.15: Average number of foxes and rabbits per hour of surveying.

Roadside counts of fox and rabbit numbers, rabbits in particular, show considerable yearly variability.

3.2.7.3 Dead vertebrates

The number of dead specimens recorded from roadsides totalled 22 in 2009. These were mainly small mammals (of which seven were dead rats). Some rabbits, cats, badgers and hedgehogs were also recorded. As in previous years, species proportions differ from living fauna, with greater representation of small mammals, hedgehogs and badgers among dead, compared with living roadside specimens.

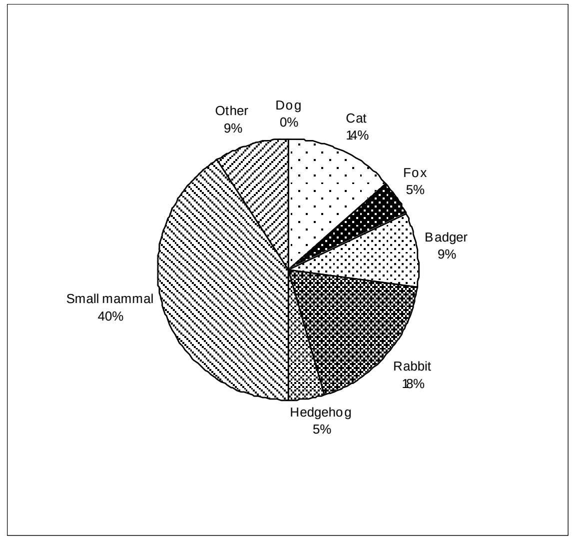


Figure 3.13: Dead vertebrates, other than bats, observed during 2009, n=22. The category ‘Small mammals’ includes rats and unidentified small mammals.

3.3 Discussion

3.3.1 Volunteer uptake

Seventy individuals, a relatively large number of volunteers, undertook the survey in 2009. The well-attended training course in Belfast ensured that a number of back-up teams were available to cover some of the Northern Ireland squares.

3.3.2 Survey Coverage in 2009

The highest number of completed surveys was achieved in 2009 compared with all previous years of the car-based surveys. In 2009, 55 surveys were undertaken, out of a possible maximum of 56. One of the surveys was abandoned before completion due to rain, while results of two others were not usable due to faults with bat detectors. So, in total, 26 surveys were successfully completed in July and the same number was successfully completed in August. A combination of back up survey teams for the North, and reduced survey time, may have contributed to this positive outcome. A number of volunteers mentioned that the reduced survey time had made the survey considerably easier to complete.

3.3.3 Dataset

The 2009 dataset consisted of 2,147 bat encounters. The common pipistrelle was the most frequently encountered species, as in all previous years, but it constituted just 45% of the bat observations compared with roughly 50% in previous years. Leisler's bat also showed a decline and in 2009 accounted for 18% of total bat encounters.

3.3.4 Species Abundance and Yearly Trends

3.3.4.1 Common pipistrelles

The activity distribution of this species followed its usual pattern with higher encounter rate squares located in the southern half of the country, although fewer squares showed very high abundance compared with previous years.

According to the trend model this species increased in the first few years of the survey reaching a peak in 2007. The peak was then followed by a decline in 2008 and 2009. Such a decline is not altogether surprising when all three summers since 2007 have been characterised by poor weather in July and August.

No significant relationship was found between common pipistrelle passes and mean monthly temperature or temperatures recorded by surveyors at the start of surveys, although in both cases the relationship was a positive one. Common pipistrelles showed a weak, non-significant negative relationship with monthly rainfall totals. The relationship between common pipistrelle activity and weather variables warrants further study.

3.3.4.2 Soprano pipistrelles

The pattern of activity distribution for the soprano pipistrelle has never been as clear as for common pipistrelles although this species does show some western bias. In 2009, however, some eastern squares, along with those in the west, recorded medium and high soprano pipistrelle abundance.

The trend for this species showed a decline in 2009 compared with 2008, but the species may still be on an overall slightly increasing trend, despite year-on-year oscillation.

It could be hypothesised that the factors that have caused a decline in common pipistrelle and the Leisler's bat over the past two/three summers have not impacted soprano pipistrelles as negatively. Results of the REML analysis, however, showed that the nature of the relationship between soprano pipistrelles and monthly temperature was positive and between rainfall and soprano passes was negative, the same as for common pipistrelles and Leisler's bat. Where the results differ for these species is at a simple square level analysis, when the nature of the relationship between soprano pipistrelles and rainfall changes to a positive (albeit non-significant) one, indicating higher soprano pipistrelle abundance in high rainfall squares. In addition, when the relationship between soprano pipistrelles and temperature is investigated in more detail it seems that the positive relationship between soprano pipistrelle passes and temperature only holds to temperatures around 18˚C, with soprano pipistrelle passes falling off at higher temperatures. This finding is of interest and should be subject to further analysis.

3.3.4.3 Leisler's Bat

As is fairly typical when examining yearly activity distribution of Leisler's bat, it is difficult to discern any particular patterns, although overall the species usually shows an eastern and southern bias (see Roche *et al.* 2009). In 2009, by way of contrast, some high encounter rate squares were located in the north-west (G89, M87), where Met Eireann noted that rainfall was lowest in the country in July and temperatures were well above normal.

Overall average encounter rates for 2009 showed a decline in Leisler's activity to 2004-2005 levels. Despite some yearly oscillation, the trend model indicates that this species increased in the first few years of the survey but has declined since 2007. Such a decline is not altogether surprising when all three summers since 2007 have been characterised by poor weather in July and August.

REML analysis showed that while the species has a positive relationship with mean monthly temperature and a negative relationship with monthly total rainfall, both of these relationships were non-significant. However, there was a highly significant positive relationship between temperature data collected by surveyors and Leisler's bat activity.

While the Leisler's bat in Ireland is not considered to migrate seasonally (Russ *et al.*, unpub.), it can fly relatively large distances in a single night. In one Irish study an individual travelled almost 50km (Russ *et al.*, unpub). It could be hypothesised that high encounters with this species in the north west in 2009, where weather conditions were favourable, along with its positive relationship with surveyor-measured evening temperatures, illustrates local or even regional movements of the species (or simply males) to localities with weather conditions favourable to foraging.

3.3.4.4 Nathusius' Pipistrelle

Nathusius' pipistrelle has increased from the zero values in the first two years of the monitoring scheme. However, it should be noted, that squares in Northern Ireland where this species has a stronghold, were not surveyed for the first few years of the survey. Due to wide error bars and overall low encounter rate GAM smoothing does not provide any insight into this species' trend. The car-based bat monitoring survey does, however, continue to add records for the species where it has not previously been encountered. Over time, it may become more apparent if the species is undergoing a major expansion.

3.3.4.5 Myotis spp.

Myotis spp. numbers seem to show reasonably constant year-year levels, although confidence limits are very wide due to the low encounter rate. This trend should not be viewed as a true representation of *Myotis* species' trends since it combines observations from three, or possibly four, species and this, along with wide error bars, means that downward trends in any of the individual *Myotis* spp. could be easily masked.

3.3.4.6 Brown Long-eared Bat

This species is the least frequently observed species from the car-based bat monitoring scheme. Results from the roost count-based monitoring scheme are shown in Section 5 of this report.

3.3.5 Reduced Survey Time

Reducing the length of the survey by five transects appeared to have had a positive effect on the number of successfully completed surveys 2009. However, there was a notable decline in Leisler's and common pipistrelle encounters in 2009. In order to be sure that this was not caused by the omission of later transects all GLM modelling was carried out with data from the first 15 transects from each survey each year. From these data it was apparent that any declines in 2009 were not caused simply by the omission of the final five transects. According to power analysis carried out in 2008, dropping the final five transects should not result in a substantial loss of power and if survey completion rates can be kept high, as in 2009, there should be little loss of power to the data.

3.3.6 Other Vertebrates

Other vertebrates were recorded in 2009 as in previous years, and again cats were the most commonly observed animal. This species showed an increase from 2006 to 2008 and, in 2009, a slight decline. Further statistical analysis, perhaps the application of a Poisson Generalised Linear Model to cat numbers, would be merited for 2010-2011.

A similar plot of mean rabbit and fox numbers shows considerable year-year oscillation in roadside observations of these species. We plan to investigate the possibilities for applying a similar Generalised Linear Model to rabbit and fox data in 2010. It may be of interest to determine whether numbers of these two species oscillate in tandem according to roadside observation data.

3.3.7 Further Data Exploration in 2010

While few of the bat activity-weather data relationships that were analysed this year showed significant results, there is still potential to further explore weather data and the influence of climate on bat activity.

Possible datasets for investigation include:

- Daily met data
  - o total daily rainfall
  - o daily minimum or maximum temperatures, sunshine hours
  - o windspeeds
- Met data for other times of the year
- The Poulter index (this is a method that rates summer weather using a formula based on mean temperature, rainfall and sunshine. The higher the index, the 'better' the summer.)
- Recorder observed data
  - o cloud cover
  - o rainfall preceding and during surveys

Multivariate techniques could be used to explore relationships. We plan to carry out this data exploration in winter 2010.

Initial investigations into the availability of habitat datasets and potential for habitat analysis were carried out early in 2010 with staff of the NPWS. This will continue in 2010 along with investigations into possible equipment upgrades so that records collected from the survey can be easily digitised.

4.0 ALL-IRELAND DAUBENTON'S BAT WATERWAY MONITORING SCHEME

4.1 Methods

The All-Ireland Daubenton's Bat Waterway Monitoring Survey methodology is based on that currently used in BCT's UK National Bat Monitoring Programme (NBMP) (Anon, 2004).

Prior to the allocation of sites, all surveyors are contacted by email to determine their participation in the coming year's surveys. All newly recruited surveyors are invited to attend an evening training course organised for the months of June and July. This training course consists of a one hour PowerPoint presentation followed by a discussion of potential survey areas. An outdoor practical session on a local river or canal to demonstrate the survey methodology is then completed. An information pack consisting of detailed description of the methodology, maps, survey forms and online training details are provided for each survey team. Heterodyne bat detectors are also available for loan for the duration of summer months.

Newly recruited surveyors are assigned a choice of 2-3 starting points located within 10km of their home address or preferred survey area. Seasoned surveyors are reassigned starting points surveyed in previous years. Starting points are selected from the EPA's National Rivers Monitoring Programme in the Republic of Ireland and the Water Quality Management Unit dataset under the NIEA, Northern Ireland.

Surveyors undertake a daytime survey of their allocated sites to determine its safety and suitability for surveying. At the chosen site, ten points (i.e. survey spots) approximately 100m apart are marked out along a 1km stretch of waterway. The surveyors then revisit the site on two evenings in August and start surveying 40 minutes after sunset. At each of the ten survey spots, the surveyor records Daubenton's bat activity as bat passes for four minutes using a heterodyne bat detector and torchlight (Walsh *et al.,* 2001).

Bat passes are either identified as 'Sure' Daubenton's bat passes or 'Unsure' Daubenton's bat passes. A 'Sure' Daubenton's bat pass is where the surveyor, using a heterodyne detector, has heard the typical rapid clicking echolocation calls of a *Myotis* species and has also clearly seen the bat skimming the water surface. Bat passes that are heard and sound like *Myotis* species but are not seen skimming the water surface may be another *Myotis* species. Therefore, these bat passes are identified as 'Unsure'. The number of times a bat passes the surveyor is counted for the duration of the four minutes. Therefore, counting bat passes is a measure of activity and results are quoted as the number of bat passes per survey period (No. of bat passes/40 minutes).

Surveyors are also requested to record a number of parameters including air temperature, weather data and waterway characteristics, such as width and smoothness.

Surveyors are asked to undertake the survey on two dates, one between the dates of 1st to 15th August (Survey 1, S1) and the repeat survey between the dates of 16th to 30th August (Survey 2, S2). On completion of surveys, survey forms are returned to BCIreland for analysis and reporting.

4.1.1 Statistical Analysis

For yearly statistical analysis a log-transformation is carried out on the data at the ten survey spots within each 1km transect survey for all years of the survey to-date (i.e. 2006-2009). This effectively calculates a geometric mean number of passes for the survey and helps to reduce the influence of very high counts recorded at some survey spots. To investigate potential relationships with collected variables, a REML model with random terms for sites and years within sites (allowing for two surveys at each site) is applied to the total number of 'Sure' Daubenton's bat passes and 'Unsure' Daubenton's bat passes. A forward stepwise fitting procedure is undertaken. Variables tested include waterway site width, air temperature, identification skills of surveyors, duration of survey and percentage of smooth surface of waterway site.

In addition, data from met stations from Met Eireann in the Republic of Ireland were compared to data collated by surveyors. This met data was added to the REML model. The data from climatological stations were used. For each survey site the distance to each met station was calculated and the rain, wind or temperature estimates formed as weighted means, with the weights being the inverse of the distances, so that the nearest stations make the greatest contribution. The median distances between sites and their nearest met station is 32km for wind, 13.7km for rainfall and 15.7km for temperature.

To assess trends, a Generalised Linear Model (GLM) with a Poisson error distribution (see Glossary) is applied to the entire dataset (i.e. 2006-2009). Confidence intervals are generated by bootstrapping at waterway site level (Fewster *et al.*, 2000, see Glossary).

This year, additional trend analysis was carried out with data from 2006-2009 using Binomial (presence/absence) Models. This essentially models the percentage of survey spots with bats present at each waterway site. Bootstrapping is used to find standard errors using logistic regression (a GLM with a logit link function). A smoothed GAM trend is also fitted to the results.

4.2 Results

4.2.1 Training and Volunteer Participation

In 2009, training courses were organised in counties Meath, Monaghan, Cork, Clare, Offaly, Dublin, Derry, Roscommon, Longford, Sligo, Tyrone, Cavan, Antrim and Limerick. Over 215 people attended these courses.

A total of 185 survey teams participated in 2009; this included 54 new survey teams. The majority of teams were composed of members of the public (n=139) and the remainder were NPWS staff (n=26) and BCIreland committee members/local bat group members (n=20).

A total of 15 different bat detector models were used by survey teams in 2009. Bat Box III Heterodyne Bat Detector was the most common model (n=48, 23%) followed by Magenta Mark III Heterodyne Bat Detector (n=26, 12.4%) and Magenta Bat 4 Heterodyne Bat Detector (n=25, 12%) (see Table A2.1, Appendix 2).

4.2.2 Waterway sites surveyed

A total of 209 waterway sites were surveyed in 2009, the highest number of waterway sites since the monitoring programme began in 2006. Thirty-five waterways sites were located in Northern Ireland and 174 waterway sites in the Republic of Ireland. Sixty-three (30%) of the waterway sites surveyed in 2009 have been surveyed each year since 2006.

In 2009 a total of 8 canals (29 waterway sites) and 114 rivers (180 waterway sites) were surveyed. The Royal Canal had 13 waterway sites surveyed along its length while the River Boyne had 8 waterway sites located along its length. Of the four provinces, the highest number of waterway sites were surveyed in Leinster (n=88) and Dublin had the highest number of waterway sites surveyed per county n=16).

4.2.3 Completed surveys

A total of 379 completed surveys from 209 waterway sites were returned to BCIreland in 2009. For Survey 1 (1st – 15th August) 195 surveys were completed and 184 surveys were completed in Survey 2 (16th – 30th August). Waterway sites with repeated surveys (i.e. surveys completed in both sampling periods S1 and S2) provide more robust data for monitoring. In 2009, a total of 169 repeated surveys (81% of waterway sites) were completed (see Figure 4.1).This was greater than the number of repeat surveys in 2008 (74%), which was poor due to adverse weather conditions, but less than 2007, which had the highest rate of repeat surveys of all four years to-date (93%).

In 2009 'Sure' Daubenton's bat passes were recorded on 186 waterway sites (89%) (see Figure 4.2). When 'Sure' and 'Unsure' Daubenton's bats passes are included, 90.9% of waterway sites surveyed had bats.

At each of the 10 survey spots of each completed survey volunteers recorded Daubenton's bat activity for 4 minutes generating 40 minutes of data per completed survey. In total, 16,780 'Sure' Daubenton's bat passes and 2,995 'Unsure' Daubenton's bat passes were recorded during 252 hours and 40 minutes of surveying. The mean number of 'Sure' Daubenton's bats passes per survey was 45.1 passes. In addition, bats were recorded on 55.3% of survey spots. Connaught, for the fourth year running, had the highest mean (Mean no. = 72.9 'Sure' bat passes) and in 2009 the highest proportion of survey spots with bats (62.1% of survey spots with bats). All provinces recorded higher mean numbers of passes than in 2008.

For a full break down of descriptive results for 2009 see Table A2.2, Appendix 2.

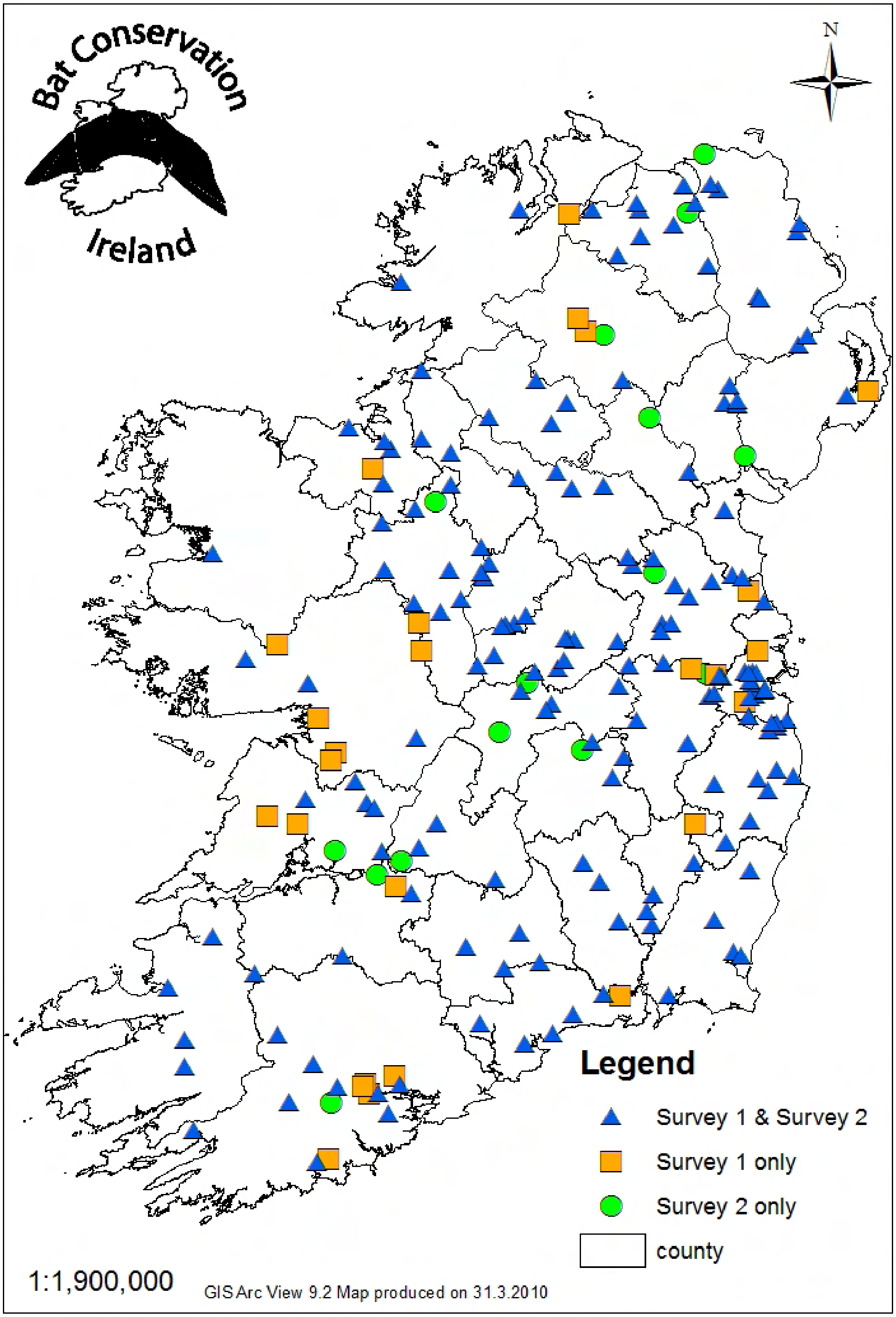


Figure 4.1: Location of all waterway sites surveyed once (Survey 1 or Survey 2 only) or twice (Survey 1 & Survey 2) in 2009.

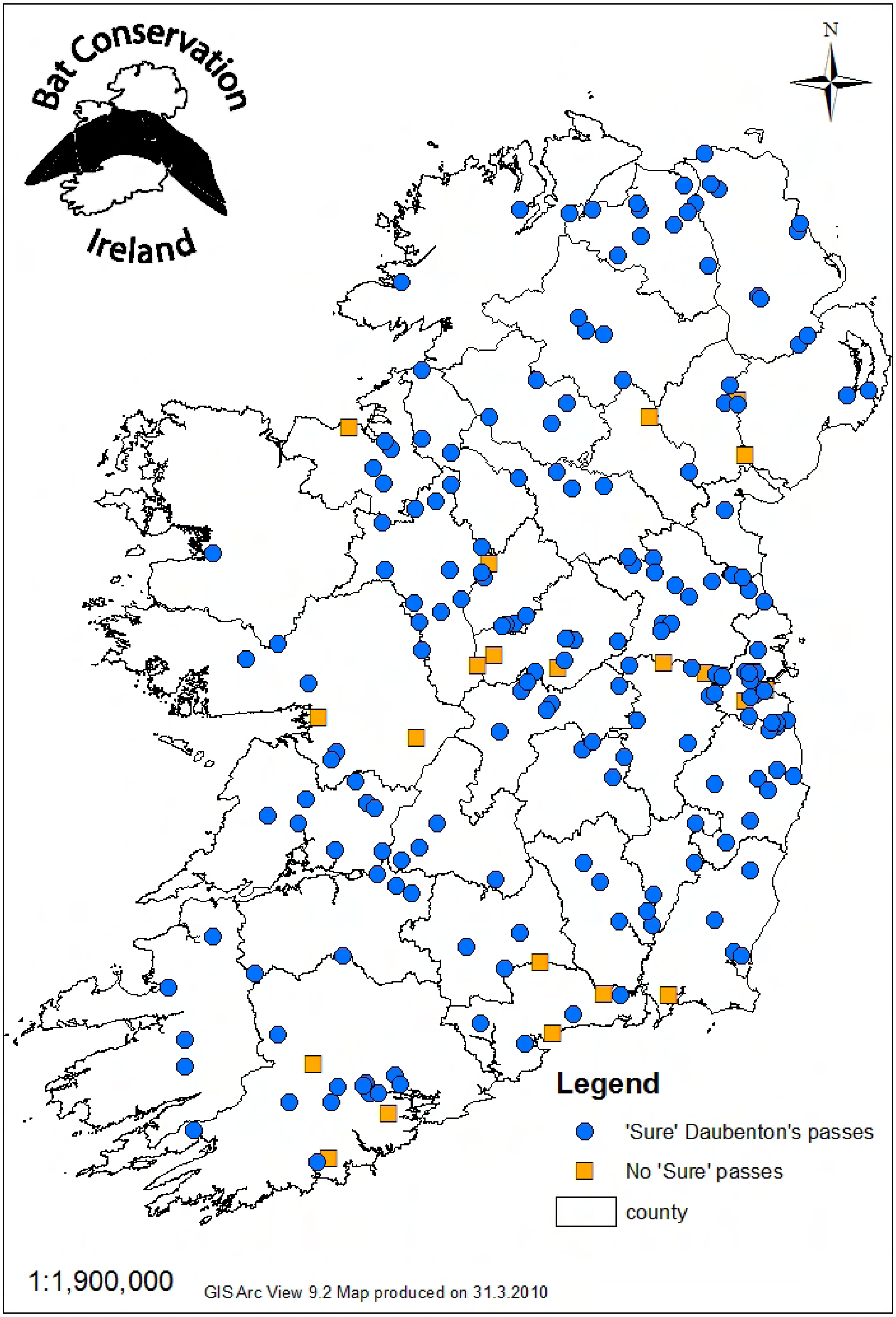


Figure 4.2: Location of all waterway sites surveyed in 2009 with records for 'Sure' Daubenton's bat passes only.

4.2.4 Distribution

A total of 334 waterway sites have been surveyed since 2006 and bat passes have been recorded at 91.5% of sites. This dataset can potentially provide information on important waterway sites for Daubenton's bats. A binomial system, the percentage of survey spots with bats present (e.g. a value of 0.7 is used if 'Sure' Daubenton's bat passes were observed at seven of the ten survey spots of a completed survey at a particular waterway site) was used to plot overall activity levels at sites across the island. While there is no obvious pattern across latitude or longitude in Figure 4.3, some of the waterway sites with a high proportion of survey spots with 'Sure' Daubenton's bat passes (i.e. dark brown representing >80%) are located along a diagonal line from County Leitrim through the midlands towards the south-east.

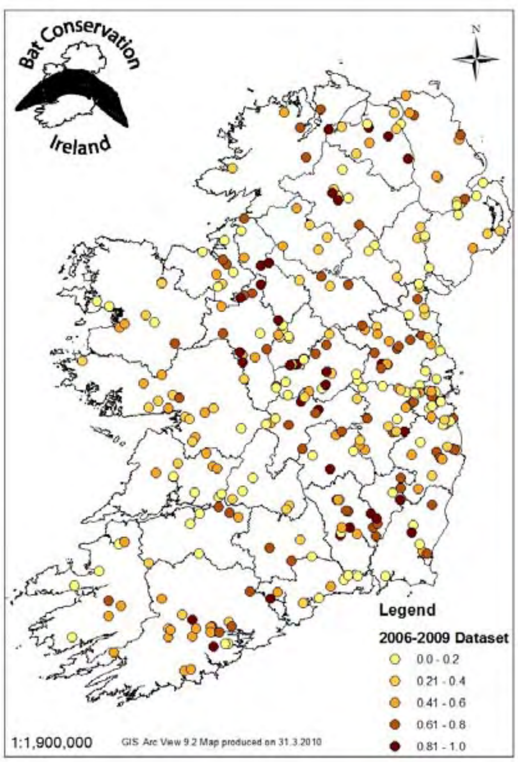


Figure 4.3: Waterway sites (n=334) colour coded according to the proportion of survey spots with 'Sure' Daubenton's bat passes, combined results from 2006-2009.

Additional waterway sites with >80% of survey spots with 'Sure' Daubenton's bat passes are located in Counties Derry, Tyrone and Cork. Waterway sites located in the west, south-west and eastern coastline have a lower proportion of survey spots with 'Sure' Daubenton's bat passes.

When this data is summarised on a County level, much of the detail seems to be lost (see Figure 4.4) with waterway sites in County Leitrim having the highest proportion survey spots with 'Sure' Daubenton's bat passes.

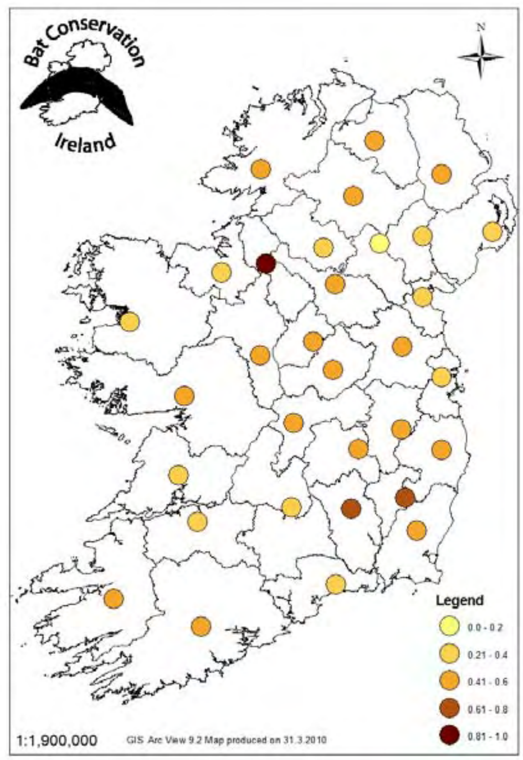


Figure 4.4: Counties colour coded according to the proportion of survey spots with 'Sure' Daubenton's bat passes, combined data from 2006-2009.

Many counties have a high number of waterway sites surveyed from year to year and a good representation of waterways located within the county. For example, Counties Dublin and Cork generally have the highest level of participation of survey teams from year to year. There are a total of 19 waterway sites in County Dublin representing six rivers (Rivers Tolka, Dodder, Liffey, Ward, Devlin and Rye Water) and 2 canals (Royal and Grand Canals). The majority of the waterway sites (n=10) surveyed in Dublin have 20% or less of survey spots with 'Sure' Daubenton's bat passes (see Figure 4.5). There are no waterway sites with greater than 80% of survey spots with 'Sure' Daubenton's bat passes. Overall, the county has an average of 21-40% of survey spots with 'Sure' Daubenton's bat passes.

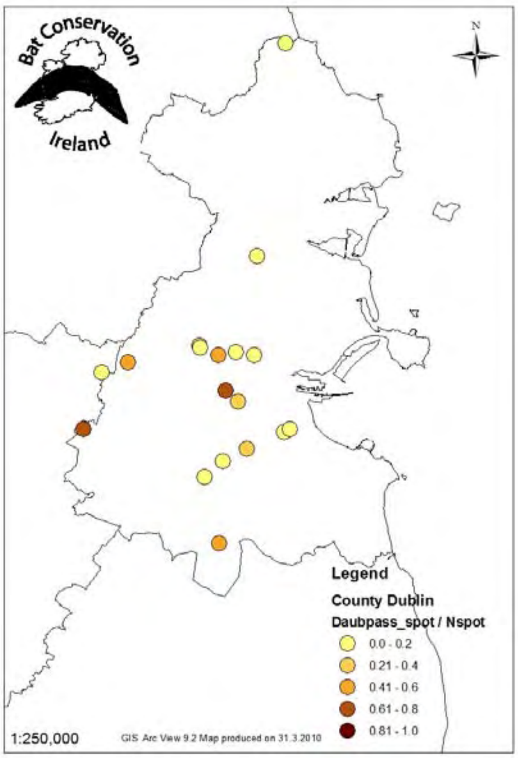


Figure 4.5: County Dublin waterway sites (n=19) colour coded according to the proportion of survey spots with 'Sure' Daubenton's bat passes, combined data from 2006-2009.

Of the 22 waterway sites in Co. Cork, 16 have been surveyed for at least two of the four years of the monitoring scheme. Sites are located on 14 rivers including the Lee, Blackwater, Owenboy and Bride. Ten of the sites have an average of 41-60% of survey spots with 'Sure' Daubenton's bat passes (see Figure 4.6). Overall, the county also has an average of 41-60% of survey spots with 'Sure' Daubenton's bat passes.

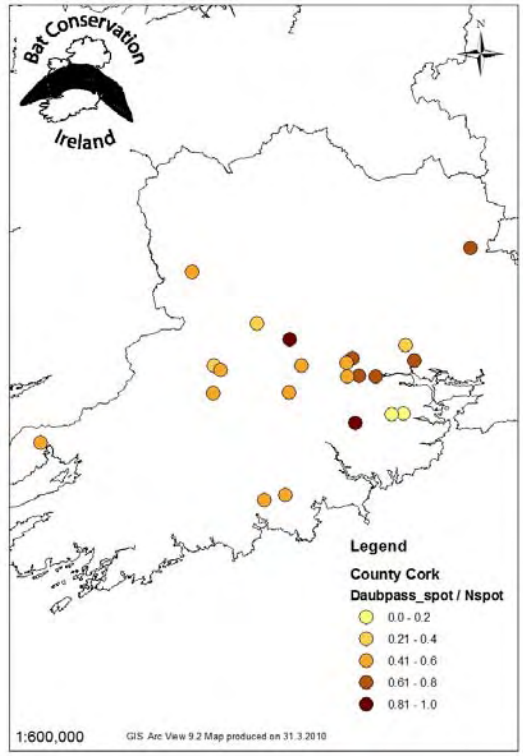


Figure 4.6: County Cork waterway sites (n=22) colour coded according to the proportion of survey spots with 'Sure' Daubenton's bat passes, combined data from 2006-2009.

County Leitrim is the only county in the country with an average of 81-100% of survey spots with 'Sure' Daubenton's bat passes. However, only five waterway sites have been sampled in this county during the four years of the monitoring scheme. Of these five sites, three have been sampled each year. While this is a small sample size compared with other more surveyed counties such as Dublin or Cork, the majority of Leitrim waterway sites had greater than 80% of survey spots with 'Sure' Daubenton's bat passes (See Figure 4.7).

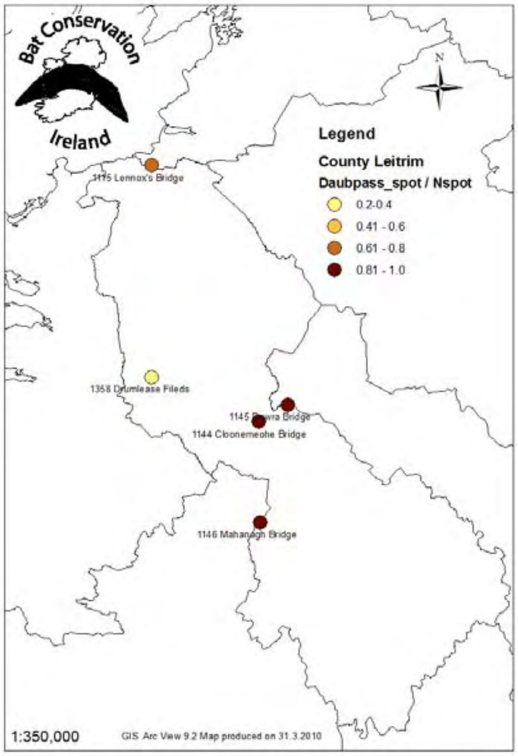


Figure 4.7: County Leitrim waterway sites (n=5) colour coded according to the proportion of survey spots with 'Sure' Daubenton's bat passes, combined data from 2006-2009.

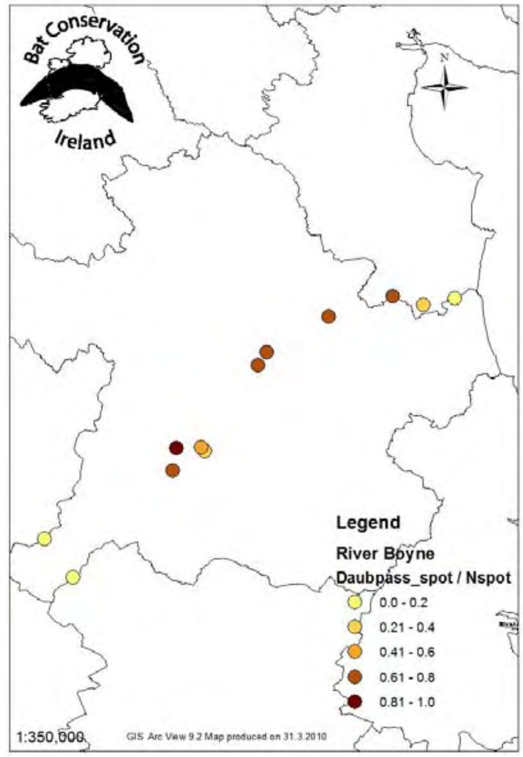


Figure 4.8: River Boyne waterway sites (n=12) colour coded according to the proportion of survey spots with 'Sure' Daubenton's bat passes, combined data from 2006-2009.

The River Boyne has 12 sampling sites in Counties Meath, Westmeath, Louth and Offaly. The upper and lower reaches of the river tended to have a lower proportion of survey spots with 'Sure' Daubenton's bat passes compared to the middle reaches of the river (See Figure 4.8). Overall the entire dataset for the river has an average of 41-60% of survey spots with Sure' Daubenton's bat passes.

4.2.5 Relationships with other variables

To investigate the relationship between log-transformed numbers of bat passes (including both 'Sure' and 'Unsure' Daubenton's bat passes) an REML model was fitted. F-tests rather than χ^2 tests were used this year, since they accommodate for the structure of the data better. To complete this task, all of the results collated from 2006 to 2009 were included. This dataset is comprised of 1328 completed surveys (See Table A2.2, Appendix 2 for further information on the entire dataset used). A total of 19 variables were tested and the results of these are shown in Tables A2.3 and A2.4, Appendix 2.

Waterway width values, as estimated by surveyors, were categorised into five groups (from <2m to >20m). The majority of waterway sites were in the 5m-10m group. This parameter was found to be highly significant with an upward trend (F = 21.56 with 1 and 536 d.f., P<0.001, fitting as linear on the log-scale). For unadjusted means, number of bat passes were highest for the waterway width category of 10.1-20m (Mean number of bat passes = 67.7, s.e. 7.86).

Air temperature was recorded by surveyors at the start of the survey night. The values recorded were grouped into five categories (e.g. <12^{o}C; 12.1-14.0^{o}C, etc). Temperature is significant at the 5% level, with a quadratic trend in the adjusted values on the log scale, as in previous years (F = 6.29 with 1 and 822 d.f., P<0.012). Mean number of bat passes were highest for the temperature category of 14.1-16.0 ^{o}C (Mean number of bat 'passes' = 56.7).

Identification skills of volunteers has a significant influence on the number of bat passes recorded (F = 2.77 with 3 and 420 d.f., P<0.041) but its significance was less than previous years (For the 2006-2008 dataset, significance was p=0.003). Volunteers who rate their identification skills as either 'good' (Mean number of bat passes' = 62.1) or 'very good' (Mean number of bat passes' = 75.8) tend to record a higher number of bat passes compared to 'poor' (Mean number of bat passes = 42.5) or 'okay' (Mean number of bat passes = 43.5) groups. Overall, the number of 'Unsure' Daubenton's bat passes recorded by surveyors has been decreasing yearly since 2006. In 2006, 'Unsure' Daubenton's bat passes represented 31% of the total number of bat passes recorded compared to only 15% in 2009.

Volunteers are requested to start surveying 40 minutes after sundown. While the majority of surveyors do follow the survey protocol, some surveys may be completed at an earlier or later time after sunset. Statistical analysis has shown that *when* surveyors start surveying (i.e. the number of minutes after sundown) is highly significant when fitted as a linear term (F = 7.40 with 1 and 816 d.f., P<0.007) using adjusted means; i.e. an increase in bat passes with later start times. When unadjusted means are examined, the number of bat passes recorded either by starting too early (e.g. before 30 minutes after sundown) or later (70-90 minutes after sundown) yielded a lower mean number of bat passes (Mean number of bat passes = 47.0 and 46.2 respectively) when compared to starting 40-50 minutes after sundown as requested (Mean number of bat passes = 57.5).

Surveyors are requested to note the time they start the survey and the time they complete the survey. While volunteers record bat activity for 40 minutes, the total length of time the survey takes is dependent on how long it takes to travel between survey spots. Consequently, factors such as ease of travel between survey spots affects the overall duration of the survey. Waterway sites that are located along canals can be completed faster than transects located along rivers edged by agricultural fields because the canal sites are facilitated by towpaths. This factor will be further investigated in 2010 with an additional question included on the survey form to determine the type of terrain present at survey sites. Time taken to complete surveys, as in previous years, remains a significant influence on the number of bat passes recorded (F = 5.94 with 1 and 946 d.f., P<0.015). Significantly fewer bat passes are recorded for 'fast' surveys (completed in less than 60 minutes) and 'slow' surveys (completed in more than 90 minutes) compared to surveys completed in 76-90 minutes (mean number of bat 'passes' = 51.2 for 'fast' surveys and 61.4 for 'slow' surveys.

This year, for the first time, the type of bat detector model used has been shown to have a significant influence on the number of bat passes recorded (F = 2.54 with 1 and 520 d.f., P<0.039). The four most common bat detector models were compared with each other and all other bat detector models were grouped under one common category. The Bat Box Duet Frequency Division/Heterodyne bat detector recorded the highest number of bat passes compared to other groups (mean number of bat passes = 77.3).

Other variables tested and found to be non-significant include surveyor experience, eastings and northings. In previous years smooth water tended to have a significant influence on the number of bat passes recorded. However, for the 2006-2009 dataset, this parameter is non-significant.

4.2.6 Met Eireann Weather Data

The relationship between the weather variables recorded by the surveyors and the data derived from the met stations collated by Met Eireann in the Republic of Ireland were investigated and the results are shown in Figure 4.9 below. Wind and rain data are illustrated with box and whisker plots, since there are too many data-points for a scatterplot to be clear given the categorical nature of the surveyors' assessment. The 'box' shows the inter-quartile range, with the central line being the median, whilst the whiskers stretch out to the minimum and maximum. There is a clear relationship between the two sets of data, with the boxes getting higher in line with the surveyors' assessments. However, there is substantial overlap between the boxes of the different categories and the non-parametric correlation coefficients are not overly large, although they are highly significant.

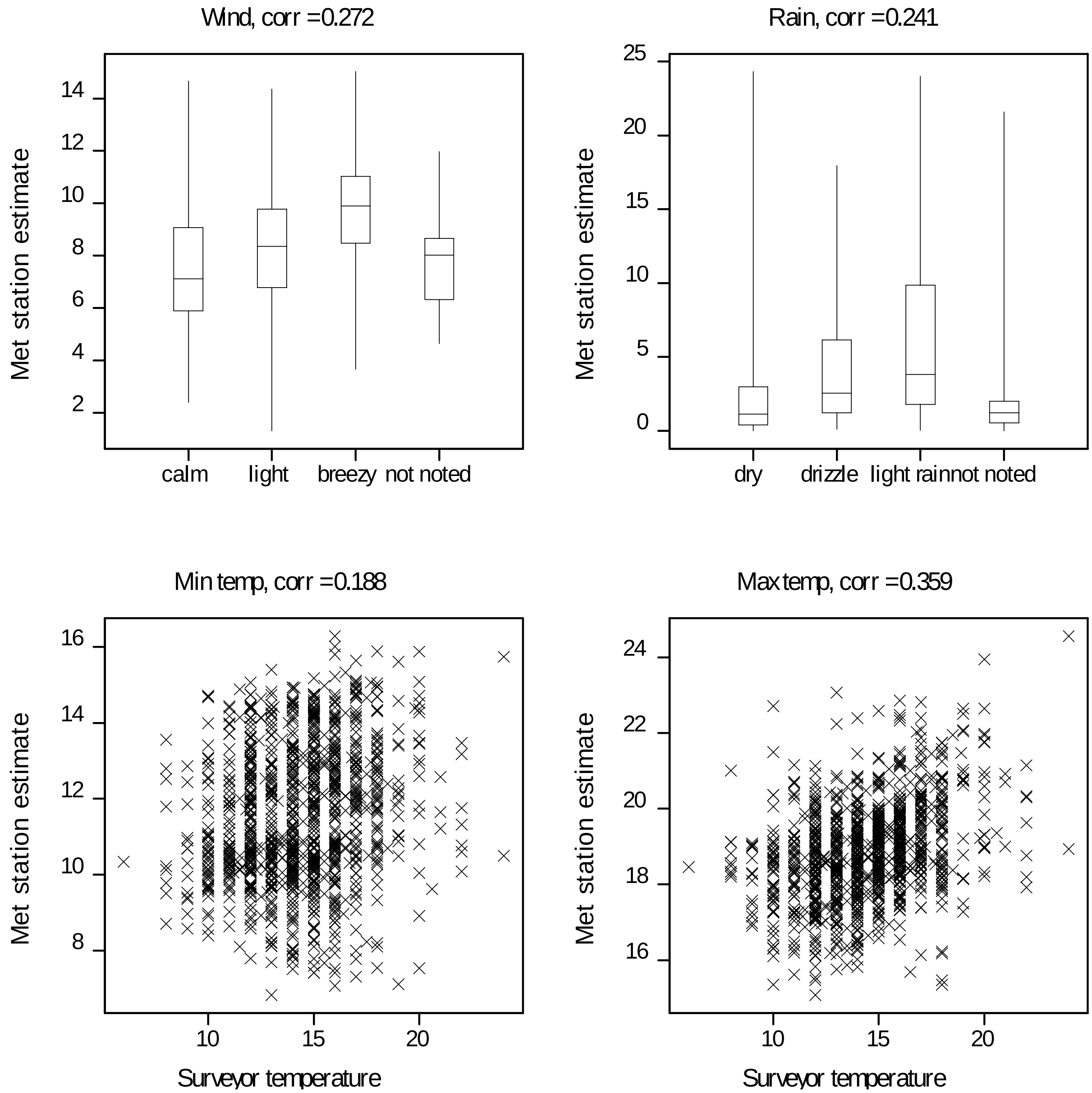
The pattern with temperature in the lower two scatterplots of Figure 4.9 is not that dissimilar; there is a significant correlation, but also a lot of variation around the relationships. The correlation is a lot stronger with the maximum temperature than the minimum temperature recorded at the met stations.

To assess the predictive power of the various met stations variables, each variable was fitted one at a time to the REML model reported previously. The results show that for wind, none of the variables is anywhere near significant.

In relation to rain, the results show that the met station version is statistically significant when added to the previous model, whereas the surveyors' categorical assessment is not ($F=1.54$ with 3 and 751 d.f., $P=0.202$) (See Figure A2.6 for additional information).

The surveyors' assessment of temperature, as reported previously, is statistically significant (($F = 6.29$ with 1 and 822 d.f., $P=0.012$). Neither of the met station temperature variables is significant, although the minimum temperature is close ($F=2.83$ with 1 and 682 d.f., $P=0.093$).

Figure 4.9 Relationships between met station variables (vertical axis) and surveyors' assessments (horizontal axis). For the categorical assessments of wind and rain, box and whisker plots are used which indicate the minimum value (lower end of whisker), the lower quartile (bottom of box), median (horizontal line), upper quartile (top of box) and maximum (top of whisker). Correlations are shown in the caption; in the case of the categorical variables these are Spearman (non-parametric) correlations.



4.2.7 Trends – GLM

To assess trends, a Poisson Generalised Linear Model was applied to the data. While a significant decline was reported for the data collated from 2006-2008, in 2009 a recovery is apparent. Daubenton's bat activity per annum was modelled using four different measures ('Sure' passes only, 'Unsure' and 'Sure' passes combined, a maximum of 48 passes per survey, a maximum of 48 passes with covariates included in the model). Since the pattern is essentially the same for the four models just two are shown in Figure 4.10 (Additional variables are shown in Figure A2.1, Appendix 2). The difference between the 2006 and 2007 values is much less in the second graph due to the exclusion of 'Unsure' Daubenton's bat passes in the analysis. This reflects the fact that surveyors tend to record more 'Unsure' Daubenton's bat passes in their first year. As the observer gains experience, there is greater confidence in correctly recording 'Sure' Daubenton's bat passes. Therefore, lower counts of 'Sure' passes can be expected for the first and perhaps second years of the survey but this does not necessarily represent the true values.

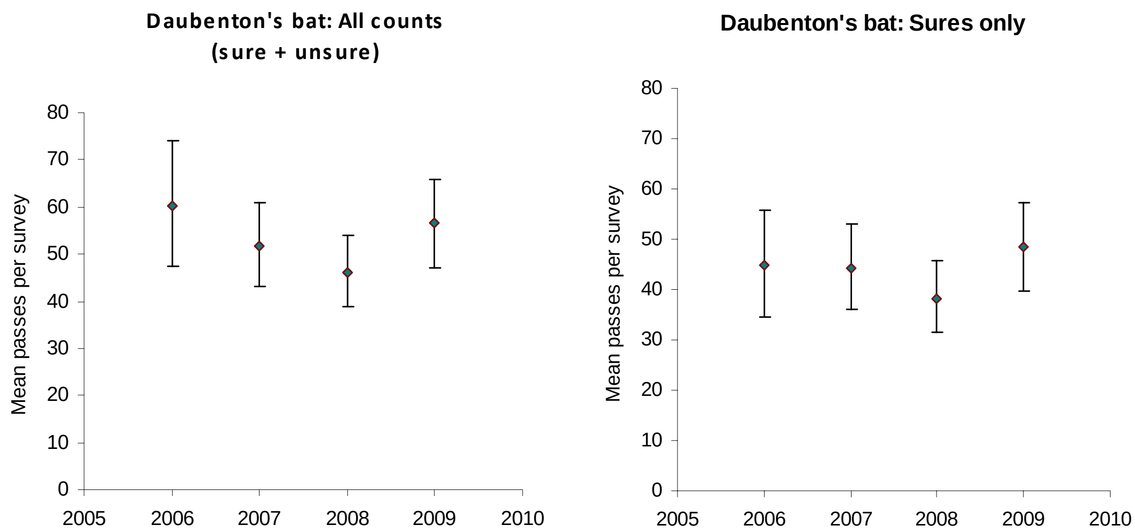


Figure 4.10: Results of the GLM for total number of Daubenton's bat passes (All counts = 'Sure' Daubenton's bat passes and 'Unsure' Daubenton's bat passes) and for total number of 'Sure' Daubenton's bat passes only. Lower numbers of 'Sure' passes can be expected in the early years of the survey, graph on right, when more inexperienced surveyors are involved. Bars are 95% bootstrapped confidence intervals.

4.2.8 Trends – Binomial GAM

For the first time in 2009, modelling using the percentage of survey spots with bats present was undertaken (e.g. response variable in the analysis is, for example, 0.7 if Daubenton's bat passes (both 'Sures' and 'Unsures' bat passes combined) were observed at seven of the ten survey spots. Analysis was also completed separately using covariates, which were determined using binomial GLMM. However the co-variates were not considered to be useful in helping to reduce the standard error of estimates so have not been included in the report. Bootstrapping is used to find the standard errors using logistic regression (a GLM with a logit link function). A smoothed GAM trend was also applied to the results. At this stage (i.e. with only 4 years of data) results suggest a decline to 2008 with numbers stabilising in 2009 (Figure 4.11) but changes are relatively small relative to the width of the confidence limits and must, therefore, be treated with caution. This type of trend analysis will become much more useful once more years of data are available. See Table A2.5, Appendix 2 for information on additional analysis.

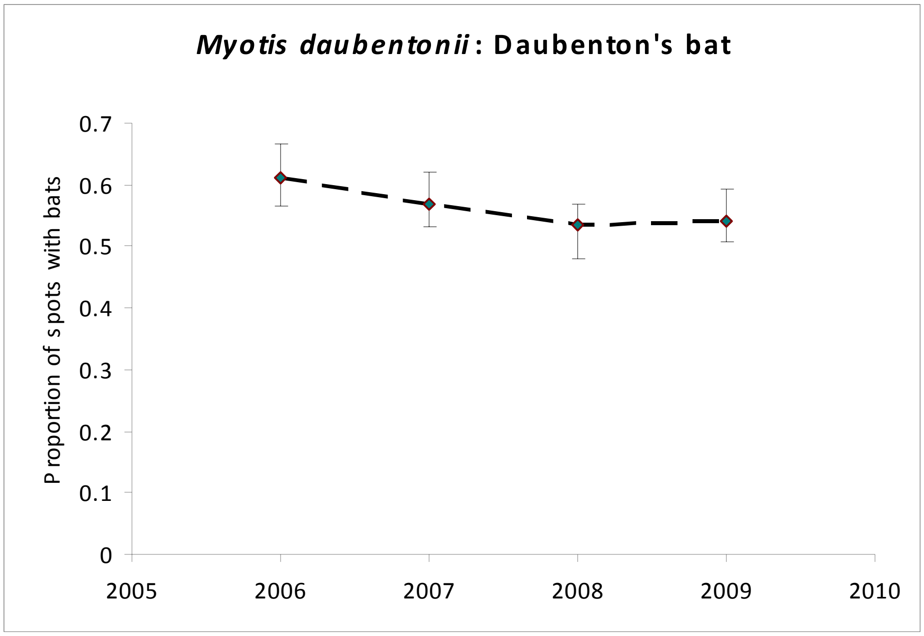


Figure 4.11: Results of the Daubenton's bat Binomial GAM/GLM without covariates. Green points are estimated annual proportions derived from the Generalised Linear Model and the bars are bootstrapped 95% confidence limits. The black dashed line is the fitted Generalised Additive Model curve with 2 d.f. The GAM curve is shown with a broken line since there are too few years of data available to determine trends with any certainty.

4.3 Discussion

4.3.1 Volunteer uptake

One hundred and eighty five survey teams (minimum two individuals per team), a relatively large number of volunteers, undertook the survey in 2009. As a result of well-attended training courses the number of new volunteer teams participating increased in 2009.

While a core group of survey teams have participated in the programme for each of the four years, there is still need for a recruitment drive each year since a certain percentage of volunteers are lost to the survey every year. The recruitment drive involves approximately 14 training courses per year. A considerable amount of work is involved in organising and running courses. However, when these are run in conjunction with local heritage or biodiversity officers in individual counties, the effort required on the part of BCIreland staff is greatly reduced and the benefit of running the event as part of the county heritage forum greatly increases their value for positive promotion of bats and wildlife conservation.

4.3.2 Survey Coverage in 2009

The highest number of completed surveys was achieved in 2009 compared with all previous years of the waterway survey. Two hundred and nine waterways sites were surveyed and a total of 379 surveys were completed. The waterway sites were located in all thirty two counties of the island with the largest coverage in Counties Dublin and Cork.

4.3.3 Dataset & Distribution

The 2009 dataset consisted of 19,775 bat passes, the majority of which were 'Sure' Daubenton's bat passes (n=16,780 bat passes). The Daubenton's bat was recorded on the majority of the waterway sites surveyed in 2009, thus re-confirming this species' wide distribution on linear waterways across the island. Daubenton's bats were recorded in every county on the island from the most northern waterway sites in Antrim to waterway sites on south west Kerry and also on waterway sites on the western seaboard in Mayo. A similar widespread distribution of this species was also reported by the BCT NBMP where Daubenton's bats were recorded from northern Scotland to southern England (www.bats.org). This monitoring scheme is, therefore, making a considerable contribution to our knowledge of the distribution range of the Daubenton's bat.

The large dataset currently held by BCIreland about this species provides a potentially useful way of mapping Daubenton's bat activity on a county, river catchment and river level. Such representation may prove useful for future county planning and conservation work in relation to waterways. BCIreland plans to continue exploring this avenue of data representation as well as further analysis in relation to water quality once further data sets are received from the EPA.

In addition, since these data are mapped on GIS it will be possible to carry out further exploration of the influence of riparian habitat (woodland in particular) and water quality once these GIS datasets become available.

Another factor that can be considered for further exploration or inclusion in habitat/water quality mixed models could be the impact of river drainage works on Daubenton's bat activity. For some rivers, such as the Boyne in County Meath, considerable lengths of the river have been subjected to drainage and straightening works. These works have been implicated in lower numbers of some protected species along the drained corridors, e.g. River and Brook Lamprey (O'Connor, 2006). The impact of such works on Daubenton's bat is unknown but there may be potential for combining information on this in a general mixed model to further explore Daubenton's bat requirements.

4.3.4 Variables affecting activity

Results from REML analysis for the four years of data suggest that several of the variables tested have a significant impact on the mean number of bat passes recorded. These include the width of waterways surveyed, air temperature recorded by volunteers at the start of the surveys, the identification skills of volunteers, start time in relation to minutes after sundown, time taken to complete surveys and for the first time in the duration of the programme, the type of bat detector model used. Smoothness of the water surface, which had a significant impact on the number of bat passes recorded in previous years, was not significant in the 2006-2009 dataset.

Width of waterway continues to be a highly significant influence on the number of bat passes recorded. The results suggest that a higher number of bat passes is recorded on Irish waterways that are 10-20m wide in comparison to all other categories. This parameter has also been found to be an important influence on the number of bat passes recorded by surveyors in previous years and corresponds to similar results in the BCT Daubenton's bat Waterway Survey.

Air temperature was also found to be significant with a greater number of bat passes recorded on moderately warm nights. On nights with a temperature lower than 12° Celsius, significantly lower bat passes were recorded. Therefore, we should continue to emphasise the importance of surveying on mild nights to ensure that chances of detecting Daubenton's bats are optimised. It is also apparent that surveyors should be encouraged to record temperature so that this variable can be allowed for when assessing trends.

Identification skills of volunteers continue to have an influence on the number of bat passes recorded. Volunteers with a greater level of skill record fewer 'Unsure' Daubenton's bat passes. With continuous recruitment being undertaken each year, there will always be a group of volunteers that will categorise their identification skills as poor or okay. However, with continued participation in the programme these volunteers will increase their skill level. This is demonstrated by the fact that the significance of this parameter has lessened over the duration of the four years.

The time at which bats emerge to feed is generally related to sunset times with additional influences including weather conditions and surrounding habitats. Daubenton's bats have been recorded only emerging from their roosts when it is fully dark (Walsh *et al*, 2001) which can range from 30-120 minutes after sunset (Swift and Racey, 1983; Altringham, 2003). This species has also been reported commuting along the most sheltered route available from roosting sites to feeding grounds (Limpens and Kapteyn, 1991). The Daubenton's Waterway Surveys start 40 minutes after sunset and results show that if surveys start earlier, there are fewer Daubenton's bat passes recorded compared to starting on time or a little later than 40 minutes after sunset. This result is not surprising given the species' known emergence characteristics.

Another important influence on the number of bat passes recorded is the duration of time the survey takes to complete. This time can vary from as little as 60 minutes up to 120 minutes plus. Surveys completed in 60 minutes record fewer bat passes compared to surveys completed in 76-90m minutes. While the survey protocol emphasises that individual spots should be surveyed for exactly 4 minutes, there is a possibility that surveyors may not be strict in the application of this. However, there is also the possibility that surveys completed in 60 minutes are those waterway sites located along tow paths, such as canals, or structured walkways while other waterway sites that take longer to survey require more 'negotiating time' by surveyors. This will be further investigated in 2010.

For the first time in the 4 years of the programme, results have indicated that the type of bat detector used by volunteers has a significant influence on the number of bat passes recorded. BCIreland has a pool of bat detectors available for use by volunteers. This pool principally consists of Bat Box Duets, Petersson D200, Bat Box III and 3D, Magenta Mark III and Magenta 4 models. The Bat Box Duet Frequency Division/Heterodyne bat detector recorded the highest number of bat passes compared to other groups. This detector model may, therefore, have a more sensitive microphone when tuned to 35kHz, the frequency that is used during the survey. It is of interest to note that the impact of bat detector model is effectively removed from overall trends or distribution mapping when the binomial method or percentage occurrence is used to represent Daubenton's bat activity, rather than total bat passes. This indicates that, while a particular bat detector model may affect the overall total number of passes observed; all models are equally effective at determining presence/absence (see 4.3.5 below).

4.3.5 Met Eireann Weather Data

The relationship between the weather variables recorded by the surveyors and the data derived from the met stations collated by Met Eireann in the Republic of Ireland were investigated. For wind and rain, there is a clear relationship between the two sets of data with substantial overlap between the different categories. The non-parametric correlation coefficients are highly significant. This is not a surprising result since a very high correlation between daily data and the weather at the time of survey, even without the location uncertainty would be expected.

There is also a significant correlation with temperatures collated by both surveyors and met stations with a stronger correlation with the maximum temperature than the minimum. This may be due to the possibility that the surveyors' measurements at the start of the survey relate more closely to the maximum recorded in the day, rather than to the minimum temperature in the night.

In relation to rain data when applied to the REML model, the results show that the met station data is statistically significant, with fewer bat passes as rainfall increases. This is interesting and it may be that the quantitative total rainfall provides a more objective assessment than the simple categorical assessment provided by surveyors, and thus outweighs the fact that it is measured over the whole day, not just the time of the survey. The most striking difference in the adjusted log means is for the 5mm or greater category, suggesting that it is picking out the very rainy days particularly poor for Daubenton's bats.

Temperature recorded by the surveyors' assessment is statistically significant while neither of the met station variables is significant, although the minimum temperature is close. Thus the surveyor's assessment appears better here, although we could consider, in 2010, whether there is any scope for using the met data to replace missing surveyor's assessments.

4.3.6 Yearly Trends

REML analysis in 2008 showed evidence of a downward trend in Daubenton's bat activity over the course of the survey from 2006-2008. Poor weather conditions in 2007 and 2008 may have been a factor influencing this decline. Poor weather conditions continued in August 2009 but Daubenton's bat activity showed a slight recovery. Additional years of data are required before making any conclusions about trends, and other factors should also be considered such as water quality and potential loss of insect diversity, which has been well documented for certain insect groups across Europe (Conrad *et al,* 2006).

In 2009 for the first time, we also examined trends using a binomial method. This is likely to be a more effective way to establish trends since the impact of bat detector model on observed passes is diminished and other effects such as surveyor skill are likely to have less of an impact on overall trends. Also, power analyses on field survey data of other species have suggested that the binomial analysis is more likely to identify trends of conservation importance. This is because using presence/absence data minimises the distortion of trends caused by multiple bat passes by the same individuals. We propose to use this binomial method as the main tool for tracking Daubenton's bat trends as the monitoring scheme progresses.

5.0 BROWN LONG-EARED BAT ROOST MONITORING

The brown long-eared bat has very low intensity echolocation calls (Russ, 1999) which means that detection of calls by bat detectors is limited to a distance of approximately 0.7m. As a result, a foot or car-based bat monitoring survey for this species will not yield sufficient data to allow monitoring of species trends. Individuals of this species tend to be roost faithful (Entwistle *et al.,* 2000). Unlike the previous two monitoring schemes, therefore, this survey involves counts of individual bats inside or emerging from roosts.

The exact methodology that is used to conduct the counts depends on factors specific to a site, such as whether there are multiple exit points and whether it is possible to access the internal roof void.

5.1 Methods

5.1.1 Preliminary roost assessment

All new roosts, when first considered for inclusion in the monitoring scheme, are assessed by completing a daytime check of the building. This involves a survey of the roof space and when the building is accessible, safe, and brown long-eared droppings or actual brown long-eared bats are observed, then a preliminary assessment is undertaken. This preliminary assessment involves surveying the building by using at least two of the methods listed in Table 5.1 below. Once a site is deemed suitable for inclusion in the scheme (i.e. more than 8 individuals are present and it is possible to safely count bats at the site by watching emerging bats or by entering the roof space), monitoring is then completed year-on-year using the most suitable method with an aim of counting the colony at each roost twice per year.

Table 5.1: Methods of assessing the most suitable protocol for counting brown long-eared bats at each roost. The assessment is carried out using at least two of Methods A-C below. Dates for surveying: Survey 1 1st May to June 15th, Survey 2 June 16th to July 31st, Survey 3 August 1st to Sept 15th.

	Method A	**Method B**	**Method C**
Description	Interior daytime count	Emergence Dusk Count	Interior Post Emergence Count
No. of counts per season	2	2 or 3	2 (usually in conjunction with Method B)
Dates when counts can be conducted	Survey 1 & Survey 3	Survey 1 (preferred), 2 and 3 (preferred)	Survey 1 & Survey 3
Surveyor	Licensed	Licence not necessary	Licensed
Method	Count of bats present in roost.	Surveyors present at all known exit points, surveying starts 20 minutes after sunset. Count in 10min blocks. Count for 100mins or stop when no bats emerge for 10-20 mins. Note if bats are seen or just heard. Direction of flight also noted.	Enter roost at start and end of emergence. Count bats present on both occasions. Numbers of bats before and after emergence are compared with total observed emerging.
Equipment	Red-light torch	Bat detector and red-light torch	Red-light torch
Other recorded details	Internal roof details, dimensions, presence of roof felt etc.	Weather conditions.	Weather conditions
Other info	Dead bats collected	Fine weather survey only.	Only undertaken in buildings with safe access in hours of darkness.

5.1.2 Yearly roost counts

Once the assessment outlined in Table 5.1 is completed, roosts that are suitable for inclusion in the scheme are monitored yearly by either Method A (2 counts) or Method B (2-3 counts) during the specified survey periods.

In general, buildings with no access to the roof space are surveyed by Emergence Dusk Counts (Method B) only. Buildings with exit points too high to clearly see emerging bats (i.e. greater than 2 floors high) are monitored using Internal Counts (Method B) if the roof space is accessible. Buildings with both access to roof space and visible exit points are assessed by whichever method that can be used with greatest ease and that results in reliable roost numbers.

On completion of surveys, survey forms are returned to BCIreland for analysis and reporting.

5.1.3 Power Analysis

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

As with the two previous monitoring schemes, two standard levels of decline – Amber Alert, representing a 25% fall over 25 years (i.e. 1.14% per year), and Red Alert, representing a 50% fall over 25 years (i.e. 2.73%) per year) – are used as the basis for the power analysis.

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

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

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

The simulations are based on all the data collected so far i.e. internal counts and emergence dusk counts. Hence the power results assume that the mix of internal and external counts will remain as at present.

5.1.4 Trend Analysis

To assess trends a Generalised Linear Model (GLM), with confidence limits based on bootstrapping at the site level was applied to the data collated from 2007-2009. To allow for differences between Internal Counts and Emergence Dusk Counts, and between the different periods (S1, S2 and S3), all counts for roosts monitored for at least 2 years, are included in the model.

5.2 Results

5.2.1 Training and Volunteer Participation in 2009

For new volunteer teams, training was provided on-site, with the scheme co-ordinator and volunteers completing the first count together. Bat detectors and torches were provided by BCIreland, where required.

A total of 45 volunteers participated in the monitoring programme in 2009. The Cork County Bat Group and Galway Bat Group were allocated 2 roosts each within their counties for monitoring. Clare and Dublin Bat Groups were allocated one roost each. Two house owners counted their own roosts in 2009. Five additional teams monitored a further eight roosts. Sixteen sites were, therefore, counted by volunteer teams while all remaining roosts were counted by the co-ordinator of the scheme.

5.2.2 Roosts surveyed

All new roosts were assessed to determine feasibility for inclusion in the monitoring scheme. In 2009, a total of 30 assessed roosts were deemed unsuitable. Seventeen of these were rejected on the basis of findings from a single day visit whereby the building was found to, for example:

- have no evidence of the presence of brown long-eared bats
- be inaccessible
- be structurally unsound or unsafe for surveying

A further 13 roosts were surveyed using two of the Methods A-C, and on the basis of the results from this assessment, were excluded from the monitoring scheme. Seven of these buildings had brown long-eared bat droppings present but no bats were detected emerging from the buildings during the Dusk emergence survey. The remaining six sites were rejected mainly because fewer than eight bats were present. Reasons why no bats or too few bats may be present in some roosts are:

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

Counts for inclusion in the monitoring dataset were carried out from the beginning of May to mid-September. A total of 38 roosts were monitored in 2009, 26 by external dusk counts, 10 by internal counts and the remaining 2 roosts using a combination of both methods (See Figure 5.1). A total of 54 external dusk counts and 21 internal counts were completed in 2009. Taking the highest count for each roost monitored, the total number of bats counted as part of the monitoring scheme in 2009 was 1,075 individuals (n=38 roosts).

5.2.2.1 Roost categories

The Chuch of Ireland church category is the largest of the six building types included in the scheme. Church of Ireland churches (n=12) tend to be 18th or 19th century buildings constructed of stone. These buildings often have a bell tower which facilitates bats entering and exiting the roof void.

Catholic churches (n=8) are mainly buildings constructed in the 20th century with large roof voids.

The Georgian house category (n=8) consists of large houses built in the 19th century with large roof voids.

Three of the four agricultural buildings were constructed of stone with the remaining one a modern barn located adjacent to a large area of deciduous woodland.

The house/bungalow (n=3) category includes smaller modern houses (when compared with the Georgian house category) built in the 20th century.

The Castle category consists of two structures, one a medieval tower and the second a 12th century stone building.

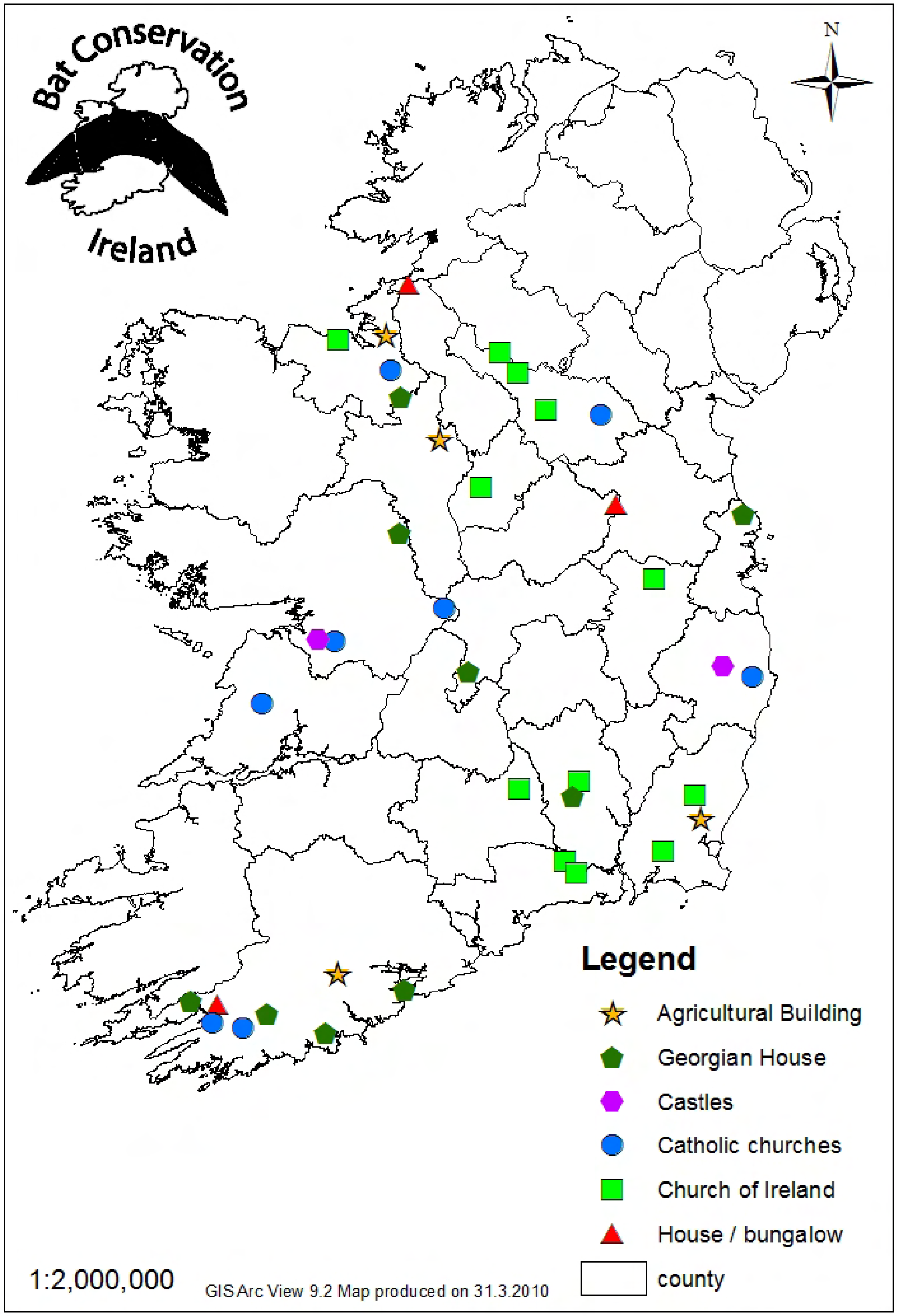


Figure 5.1: Location of brown long-eared roosts monitored in 2009 categorising the different building types surveyed (N=38).

5.2.3 Completed monitoring surveys

Seventy-five monitoring surveys were completed in 2009 and these were carried out from the beginning of May to mid-September.

A total of 25 surveys were completed in Survey 1 (1st May-15th June) and the average number of bats per roost was 22.36 (Total no. = 559 individuals, S.E. = ±2.65). During Survey 2 (16th June – 31st July) a total of 19 surveys were completed and the average number of bats per roost was 23.33 (Total no. = 420 individuals, S.E. = ±4.56). A total of 32 surveys were completed during Survey 3 (1st August – 15th September) and the average number bats per roost was 27.91 (Total no. = 893 individuals, S.E. = ±3.13).

In relation to the 54 emergence dusk counts completed in 2009, 15 were completed in S1, 14 in S2 and 25 in S3. The average number of bats for each survey period is shown in Figure 5.2a. In relation to the 21 Internal Counts, 10 were completed in S1, 4 in S2 and 7 in S3. The average number of bats for each survey period is shown in Figure 5.2b. There are a higher average number of bats counted in S3 compared to S1 during Internal Counts, which is to be expected. The average number of bats recorded during the Dusk Emergence Counts is relatively similar between all three survey periods.

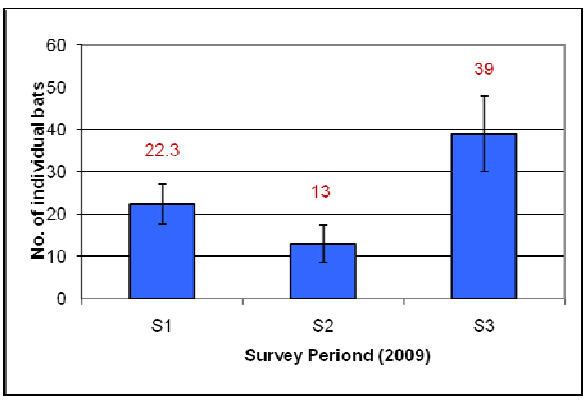


Figure 5.2a: The average number of bats at roosts counted internally for each survey period. (S1, n=10; S2, n=4; S3, n=7) with 95% standard error bars.

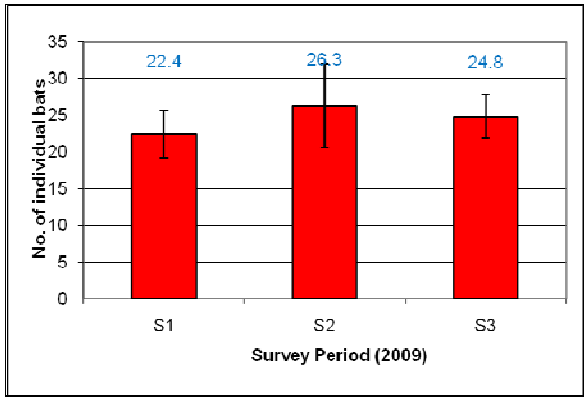


Figure 5.2b: The average number of bats at roosts counted by Dusk Emergence Counts for each survey period. (S1, n=15; S2, n=14; S3, n=25) with 95% standard error bars.

5.2.4 Power analysis

Results of power analysis using two counts per year with varying number of roosts, based on 2007-2009 count data, are shown in Tables 5.1a and 5.1b. Individual values are subject to the usual estimating errors so it is necessary to take a broad view of the trend with increasing numbers of roosts, rather than focusing too much on individual values.

Table 5.1a shows the results of investigations into amber and red alert declines (i.e. 25% or 50% declines over 25 years). Table 5.1b shows number of years' surveying required to determine a 50% increase over 25 years.

Table 5.1: Number of years (including the extra years needed at either end of the GAM curve) to achieve 80% power for various increasing or decreasing population scenarios. Whilst the number of years must be an integer in reality results are shown here with one decimal place to aid comparisons.

a) Amber and red alert decreases
(i.e. 25% or 50% decline over 25 years)

	Years for 80% power			
	Red alert		Amber alert	
Sites	Estimate	s.e.	Estimate	s.e.
20	10.0	0.6	20.7	1.3
30	8.7	0.4	17.7	1.2
40	8.1	0.4	14.7	1.0
50	7.5	0.4	13.6	1.0
75	6.8	0.4	11.7	0.5
100	6.4	0.3	10.3	0.5
125	5.8	0.3	9.8	0.4
150	5.4	0.3	9.3	0.4

b) 50% increase over 25 years.

	Years for 80% power 50% increase	
Sites	Estimate	s.e.
20	14.8	0.8
30	13.4	0.7
40	11.7	0.4
50	10.9	0.4
75	9.8	0.5
100	8.6	0.3
125	8.2	0.3
150	7.8	0.3

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

It is worth noting that, as for other monitoring schemes, the impact on power, of adding more survey sites lessens as the number of sites increases. For example, by increasing the number of sites surveyed by 25 from 125 to 150 just decreases the number of years required to detect a red alert decline by 0.4, whereas at lower site numbers (e.g. 20) the addition of 20 new sites (to 40) results in lowering the number of years required for red alert detection by almost two. This effect is even more pronounced for amber alert decline detection. Thus, the current aim, to survey 30 to 50 roosts per annum (minimum 2 counts per year), is probably quite reasonable in optimising surveyor effort but still deriving robust results. Following on from this, if 30 roosts were surveyed twice annually, then red and amber alert declines should be detectable by 8.7 years and 17.7 years, respectively. If 50 roosts were surveyed twice per year the number of years of surveying required would change to 7.5 years and 13.6 years, respectively.

The results in Table 5.1a and b are based on simulations in which each roost is observed twice in every year, whereas missing counts are inevitable in practice. If the missing observations are at random then the impact is roughly proportional to the number of missing counts; for example, if 100 roosts are known but around 20 are not observed in any one year, the power will be roughly the same as observing 80 roosts continuously. If, as is more likely, the missing observations are non-random (for example, if a roost is observed continuously for 5 years, then not observed for the next few years), the impact will tend to be much greater.

5.2.5 Trends

Figure 5.3 shows results from a Generalised Linear Model (GLM), with confidence limits based on bootstrapping at the site level. To allow for differences between Internal Counts and Emergence Dusk Counts, and between the different periods (S1, S2 and S3), all counts for roosts monitored for at least two years from 2007-2009, have been included in the model, rather than just the maximum count in each year as used in the NMBP. No trend has been fitted, given that there are only three years of data.

On examining Figure 5.3 (and Table A3.2, Appendix 3) the fitted mean is slightly higher in 2009, but the difference is small relative to the confidence limits, so this is not significant. Interestingly, despite the smaller sample size, confidence limits are narrower in 2007 than in later years. This is because the 2007 counts were less variable, with a high proportion between 10 and 35, and no very large counts (See Figure A3.1a, b and c, Appendix 3 for illustrative histograms).

Fitting a Generalised Linear Mixed Model (GLMM) with a Poisson error distribution indicates that the interaction between year and period is significant (F=2.88 with 4 and 104 d.f., P=0.026); this is because mean counts in Survey 3 were lower in 2007 and 2008, but remained at similar levels to Survey 2 in 2009. The interaction between roost type and years is also significant at the 5% level (F=3.51 with 2 and 86 d.f., P=0.034); emergence counts always tend to be higher, but this effect was more pronounced in 2009.

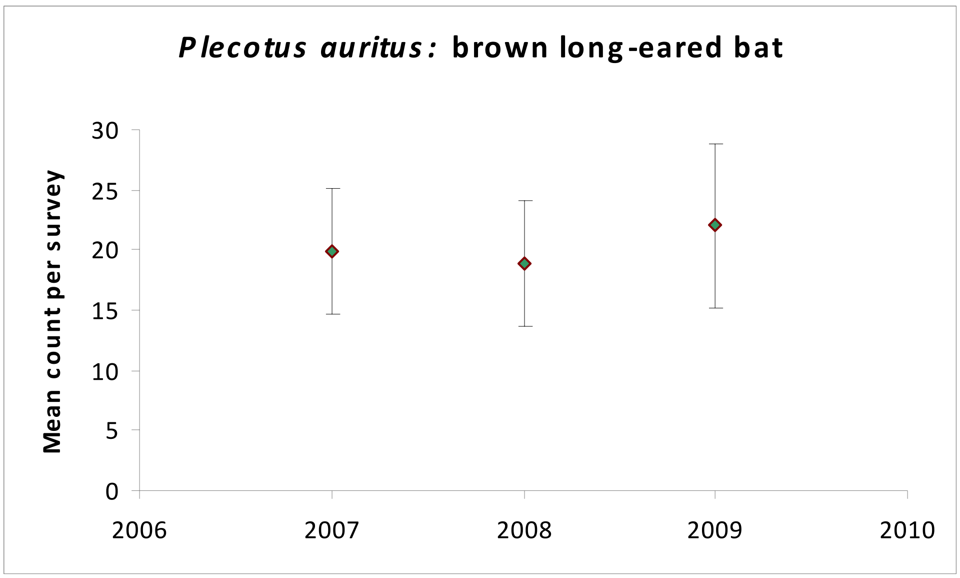


Figure 5.3: Results of the GLM model for brown long-eared bat counts per survey. Green points are estimated annual means derived from the Generalised Linear Model and the bars are 95% bootstrapped confidence limits.

5.3 Discussion

5.3.1 Volunteer uptake

Volunteers recruited for this monitoring scheme need to have more experience identifying bats using bat detectors compared to volunteers recruited for the All-Ireland Daubenton's Bat Waterway Survey. Therefore, there is a smaller pool of volunteers with sufficient expertise available to participate in the scheme. However, teams organised to-date have carried out the counts very successfully, especially when a team leader is assigned to organise survey dates, collate survey results and return datasheets to BCIreland.

However, there is currently a very high time commitment from the co-ordinator and considerable car-mile coverage involved in carrying out counts and preliminary assessments among sites that are widely dispersed around the country. Therefore, particularly, when the assessment of sites has been completed, it would be desirable to increase the number of volunteer survey teams who can carry out counts in their own localities. Of the 38 roosts monitored in 2009, 26 of these were monitored solely by Dusk Emergence Counts, 14 by volunteer teams. Volunteer teams, with training, could be assigned to at least a further eight roosts. With this is mind, we aim to carry out further volunteer recruitment in 2010 with an aim to have greater than 50% of roosts monitored by volunteer teams and roost owners. Volunteers participating in other monitoring schemes and people who have attended bat detector workshops will be contacted to determine their interest in joining a local team to monitor a roost within their county. This will help ensure that the scheme can be carried out more cost effectively henceforth.

5.3.2 Survey Coverage in 2009

More roost assessments and surveys were completed in 2009 compared to 2008 and 2007. Brown long-eared roosts in seventeen counties were surveyed.

5.3.3 Dataset

To-date, 102 buildings have been checked for inclusion in the monitoring programme. Only 42 of these have been ear-marked for inclusion in the yearly monitoring scheme. A further 16 buildings are timetabled for investigation in the coming field season. Survey work needs to be prioritised in some of the remaining counties, such as Mayo, Donegal, Limerick and Kerry, in 2010 to ensure that there is a representative spread of roosts for monitoring across the entire country. It is the aim of the scheme to identify up to 50 roosts suitable for yearly monitoring. BCIreland is on the way to achieving this target but will prioritise, in 2010, recruitment of volunteers and roosts assessments in areas of the country where there are gaps in coverage.

5.3.4 Power analysis

In theory red alert declines in brown long-eared bats can be detected relatively quickly (in 10 years with only 20 sites). In practice, however, there would be concerns about the representativeness of such a small survey. Much larger numbers are, as would be expected, needed for amber alert detection, nevertheless they can be identified 80% of the time within 10 years with just over a hundred sites. However, surveying such a large number of sites would require a much greater survey effort from the small pool of experienced bat workers that currently exists.

Simulations for power analysis assume that the current mix of roosts monitored by Internal Counts and Emergence Dusk Counts will continue. Surprisingly, internal counts are rather more variable, so if these were more common in the future, more roosts would need to be surveyed to achieve the same power. Therefore, where possible and where volunteer effort is available, Emergence Dusk Count should be prioritised as the method used for monitoring roosts.

The aim of this current 3-year monitoring programme is to identify 50 roosts suitable for monitoring. Results from power analysis have now confirmed that this will provide a robust dataset for detecting red and amber alerts. If a minimum of 30 from this pool of roosts are surveyed with two counts every year, red and amber alerts should be detectable by 8.7 years and 17.7 years respectively. If all 50 roosts are counted twice per annum red and amber alert declines would be detectable in 7.5 years and 13.6 years respectively. The time needed to detect a 50% increase is intermediate between a red and amber alert decline.

While it is good practice to monitor the same roosts each year, in reality poor weather conditions, loss of roosts, lack of volunteers etc., may result in some roosts not being surveyed in any particular year. Therefore, if the power analysis results associated with 30 roosts are considered reasonable, it would for example, be prudent to aim to survey approximately

30% more than 30 roosts (twice annually) per year, i.e. roughly 40 roosts. The exact target number of roosts for yearly counts can be decided when the final field season (2010) has been carried out for the present contract, a full spread of roosts is available across the country and as many volunteers have been recruited as possible. The roost count targets from 2011 onwards will probably have to be derived from a compromise between available financial and manpower resources and achieving reasonable power with a sufficiently large dataset.

Power analysis will be undertaken again in 2010 to aid this decision making process.

5.3.5 Yearly Trends

Due to the small sample size, caution is need in interpreting the yearly trend results because there are signs of interactions between both survey type and number of years of surveying, and period (S1 or S2 or S3) and actual survey years. Emergence Dusk Counts tended to yield higher count numbers compared to Internal Counts especially in 2009. More years of data are needed to determine more accurately the extent of interactions and to determine if any trends are apparent.

Further trend analysis will be undertaken in 2010.

5.3.6 Habitats

This species is considered by Swift and Racey (1993) to be strongly associated with woodland. Roost sites are often close to woodland areas to allow individuals to reduce travel time between roosting sites and foraging areas (Altringham, 2003). In addition, natural linear features such as hedgerows and treelines are important features for this species. Therefore, in 2010, a preliminary assessment of habitats within a 5km radius of selection of roughly 10 roosts will be undertaken. This information may help to provide criteria for locating additional roosting sites, but will it also contribute further to our understanding of the ecological and conservation requirements of brown long-eared bats in Ireland where little research of this kind has been carried out.

6.0 References and Sources of Information

Altringham, J. D. (2003). British Bats. Harper Collins Publishers.

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

Aughney, T., Carden, R. and Roche, N. (2009) Irish Bat Monitoring and Recording Schemes: Annual Report 2008. Bat Conservation Ireland. www.batconsevationireland.org.

Aughney, T. and Roche, N. (2006) Proposals and Recommendations for a Pilot Daubenton's Bat Waterways Survey: Irish Bat Monitoring Programme. Bat Conservation Ireland. www.batconservationireland.org.

Aughney, T. and Roche, N. (2008) Brown long-eared bat *Plecotus auritus* roost monitoring 2007. Irish Bat Monitoring Programme. Bat Conservation Ireland. www.batconservationireland.org.

Aughney, T. et al (2007) All Ireland Daubenton's Bat Waterway Monitoring Scheme 2006: Irish Bat Monitoring programme. Bat Conservation Ireland www.batconservationireland.org.

Aughney, T., Langton, S. and Roche, N. (2009) All Ireland Daubenton's Bat Waterway Monitoring Scheme: Synthesis Report for 2006-2008. *Irish Wildlife Manuals* No. 42. National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government.

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

Catto, C., Russ, J. and Langton, S. (2004). Development of a Car Survey Monitoring Protocol for the Republic of Ireland. The Heritage Council, Kilkenny, Ireland.

Catto, C., Coyte, A., Agate, J. and Langton, S. (2003). Bats as indicators of environmental quality. R&D Technical Report E1-129/TR, Environmental Agency, UK.

Conrad, K.F., Warren, M. S., Fox, R., Parson, M. S., Woiwood, I. P. (2006). Rapid declines of common, widespread British moths provide evidence of an insect biodiversity crisis. *Biological Conservation*, 132: 179-291.

Entwistle, A.C.; Racey, P.A. and Speakman, J.R. (2000) Social and population structure of a gleaning bat, *Plecotus auritus. Journal of Zoology,* 252, 11-17.

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.

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

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

Marnell, F., Kingston, N. and Looney, D. (2009). Ireland Red List No. 3: Terrestrial Mammals. National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Dublin.

Mitchell-Jones, A.J., Amori, G., Bogdanowicz, W., Krystufek, B., Reijnders, P.J.H., Spitzenberger, F., Stubbe, M., Thissen, J.B.M., Vohralik, V. and Zima, J. (1999). The Atlas of European Mammals. Poyser Natural History.

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

O'Connor W. (2006). A survey of juvenile lamprey populations in the Boyne Catchment. *Irish Wildlife Manuals*, No. 24 National Parks and Wildlife Service, Department of Environment, Heritage and Local Government, Dublin, Ireland.

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. and Aughney, T. (2009) The Car Based Bat Monitoring Scheme for Ireland: Synthesis Report 2003-2008. *Irish Wildlife Manuals*, No. 39. 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.

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

Russ, J. M. (1999). The Bats of Britain and Ireland: Echolocation, Sound Analysis and Species Identification. Alana Books, Powys.

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

Swift, S.M. and Racey, P.A. (1983.) Resource partitioning in two species of vespertilionid bats (Chiroptera) occupying the same roost. *Journal of Zoology (London),* 200: 249-259.

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

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.

Walsh, A., Catto, C., Hutson, T., Racey, P., Richardson, P. and Langton, S. (2001). The UK's National Bat Monitoring Programme, Final Report 2001. Bat Conservation Trust UK.

Whilde, T. (1993). Threatened mammals, birds, amphibians and fish in Ireland. Irish Red Data Book 2: Vertebrates. HMSO, Belfast.

7.0 Glossary

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

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

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

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

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

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

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

Power Analysis
Analysis of the power (probability) to reject a false null hypothesis. A test with high power has a large chance of rejecting the null hypothesis when this hypothesis is false. In the case of the present project the null hypothesis would state that that there is no decline in bat populations. Power is measured as a percentage, and greater power reflects the increased likelihood of detecting a declining trend (as outlined for Red or Amber Alerts). The power analysis carried out for the present project is one-tailed (i.e. examines a declining trend only) at P=0.05 (which is equivalent to P=0.l for a two sided test).

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

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● All Ireland Daubenton's Bat Waterway Monitoring Scheme
● Brown long-eared Roost Monitoring Scheme for the Republic of Ireland

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NIEA Northern Ireland Environment Agency
www.ni-environment.gov.uk

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

APPENDIX 1

Car-Based Bat Monitoring

Table A1.1: Average number of bat encounters per hour for each survey square, Survey 1, 2009 (number of 1 mile transects (n) = 15 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.

Square	Ppip	Ppyg	Pipun	*Myotis* spp.	Nl	Pnath	Brown long-eared	Total
C72								
G20	8.035	18.078	4.017	0.000	1.004	0.000	0.000	31.135
G53	1.083	14.075	3.248	0.000	1.083	0.000	0.000	19.489
G89	8.811	6.608	2.203	0.000	31.939	0.000	2.203	51.763
H13	25.923	20.738	2.074	0.000	12.443	0.000	0.000	62.214
H40	15.039	10.026	7.018	1.003	2.005	0.000	0.000	35.091
H79	6.928	2.969	0.000	0.000	9.897	13.856	0.990	34.639
J06	6.561	11.248	0.000	0.937	21.559	3.749	0.000	44.055
J33	10.817	2.163	5.408	0.000	2.163	0.000	0.000	20.552
L64	0.000	1.082	0.000	1.082	0.000	0.000	0.000	2.163
M24	20.498	19.473	0.000	0.000	4.100	0.000	0.000	44.071
M87	5.938	5.938	0.000	2.969	5.938	0.000	0.000	20.784
N11	10.008	2.224	3.336	0.000	0.000	0.000	0.000	15.568
N74	31.779	2.270	1.135	0.000	5.675	0.000	0.000	40.859
N77	11.755	9.618	2.137	0.000	10.686	0.000	1.069	35.265
O04	15.704	3.365	1.122	0.000	3.365	0.000	0.000	23.556
R22	12.576	20.961	5.031	0.838	1.677	0.000	0.000	41.921
R28	23.040	31.269	17.280	3.291	1.646	0.000	0.000	77.349
R88	31.400	5.888	1.963	0.000	3.925	1.963	0.000	45.138
S12	33.501	8.645	6.484	2.161	4.323	0.000	0.000	55.114
S15	26.791	3.695	2.771	0.000	5.543	0.000	0.000	39.724
S78	53.132	27.774	12.075	0.000	0.000	0.000	0.000	92.981
T05	30.419	1.963	3.925	0.000	3.925	0.000	0.000	40.232
V93	51.679	11.843	11.843	1.077	15.073	0.000	0.000	91.514
V96	19.620	12.146	3.737	0.000	16.818	0.934	0.000	53.255
V99	25.825	2.246	1.123	1.123	6.737	2.246	0.000	39.298
W56	35.056	10.879	3.626	0.000	8.462	0.000	2.418	62.858
X49	29.086	19.737	2.078	0.000	7.271	0.000	0.000	58.171
Average	**20.408**	**10.627**	**3.838**	**0.536**	**6.935**	**0.843**	**0.247**	**43.658**
Stdev	*±13.890*	*±8.403*	*±4.144*	*±0.935*	*±7.404*	*±2.750*	*±0.655*	*±21.545*

Table A1.2: Average number of bat encounters per hour for each survey square, Survey 2, 2009 (number of 1 mile transects (n) = 15 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.

Square	Ppip	Ppyg	Pipun	*Myotis* spp.	Nl	Pnath	Brown long-eared	Total
C72	9.521	9.521	1.058	0.000	3.174	0.000	0.000	23.273
G20	9.201	2.760	4.601	0.000	0.000	0.000	0.000	16.562
G53	5.460	13.103	2.184	0.000	3.276	0.000	0.000	25.115
G89	5.403	3.242	0.000	0.000	12.968	0.000	0.000	21.614
H13	19.762	4.650	0.000	0.000	4.650	1.162	1.162	31.386
H40	12.595	37.786	1.938	0.969	6.782	0.000	0.000	61.040
H79	6.188	4.125	0.000	0.000	10.313	0.000	0.000	20.627
J06								
J33	7.867	1.124	1.124	1.124	2.248	0.000	0.000	13.487
L64	0.000	7.806	2.230	0.000	0.000	0.000	0.000	10.037
M24	27.032	8.318	2.079	0.000	3.119	0.000	0.000	40.549
M87	12.443	8.295	0.000	0.000	23.849	0.000	0.000	44.587
N11	16.583	0.000	0.000	0.000	2.211	0.000	0.000	18.795
N74	16.974	0.000	1.132	0.000	5.658	0.000	0.000	23.764
N77	29.178	7.565	6.484	0.000	22.694	0.000	0.000	65.921
O04	31.377	1.121	1.121	0.000	3.362	1.121	0.000	38.101
R22	30.022	19.729	9.436	0.000	4.289	0.000	0.858	66.049
R28	25.479	40.948	9.100	0.000	3.640	0.000	0.000	79.166
R88	26.470	8.056	2.302	0.000	4.603	0.000	1.151	42.581
S12	12.908	11.832	1.076	2.151	32.269	0.000	0.000	60.235
S15	29.650	2.616	4.360	1.744	5.232	0.000	0.000	44.475
S78	31.706	30.532	7.046	0.000	4.697	0.000	0.000	73.982
T05	14.889	3.722	2.792	0.000	11.166	0.000	0.000	32.569
V93	31.276	27.106	4.170	3.128	9.383	0.000	0.000	75.062
V96	17.496	20.259	4.604	0.921	19.338	0.000	0.000	62.619
V99	18.694	0.000	0.000	0.000	10.515	1.168	0.000	30.377
W56								
X49	7.080	6.068	2.023	0.000	5.057	0.000	0.000	20.228
Survey 2	**17.510**	**10.780**	**2.725**	**0.386**	**8.250**	**0.133**	**0.122**	**40.085**
	±9.807	*±11.644*	*±2.759*	*±0.816*	*±8.016*	*±0.375*	*±0.348*	*±21.331*

APPENDIX 2

All-Ireland Daubenton's Bat Waterway Survey

Table A2.1: Bat detector models used by survey teams in different years (2006-2009).
The table shows numbers of sites, and percentages, excluding those outside the usual date range.

	Numbers of surveys				**Percentage of surveys**			
year	**2006**	**2007**	**2008**	**2009**	**2006**	**2007**	**2008**	**2009**
Detector model								
Magenta Mk II	5	7	2	1	3.7	3.5	1.1	0.5
Magenta Mk III	31	34	31	26	23.1	16.9	17.2	12.4
Bat Box III	47	61	47	48	35.1	30.3	26.1	23.0
Pettersson D100	10	18	21	23	7.5	9.0	11.7	11.0
Pettersson D200	10	17	9	10	7.5	8.5	5.0	4.8
Bat box Duet	6	16	24	24	4.5	8.0	13.3	11.5
Pettersson D230	3	4	3	1	2.2	2.0	1.7	0.5
Pettersson D240x	5	6	8	6	3.7	3.0	4.4	2.9
Sky SBR 2100	2	1	0	0	1.5	0.5	0.0	0.0
Mini-3	4	2	2	8	3.0	1.0	1.1	3.8
Magenta Bat 4	0	1	3	25	0.0	0.5	1.7	12.0
Not noted	11	17	6	10	8.2	8.5	3.3	4.8
U30 Bat Detector	0	1	0	0	0.0	0.5	0.0	0.0
Bat Box IIId	0	16	17	10	0.0	8.0	9.4	4.8
Magenta Bat 5	0	0	0	3	0.0	0.0	0.0	1.4
Ciel Electronics	0	0	7	13	0.0	0.0	3.9	6.2
Anabat	0	0	0	1	0.0	0.0	0.0	0.5
All detectors	**134**	**201**	**180**	**209**	**100%**	**100%**	**100%**	**100%**

Note: For 2007 dataset, the total number of waterway sites is 201, 2 sites greater than was reported in the 2007 annual report. This is due to late submission of 2 survey forms which have been included in the full dataset for this monitoring scheme subsequently.

Table A2.2: Basic descriptive statistics shown by year and province.

The final column refers to surveys with either ‘Sure’ or ‘Unsure’ Daubenton’s bat ‘passes’. All values are per completed survey of 10 survey spot counts.

	Connaght						
Year	n completed surveys	mean sure	mean unsure	all	All (max 48 per spot)	% surveys with bats	% spots with bats
2006	51	66.1	21.6	87.7	77.1	92.2	55.7
2007	60	54.8	10.3	65.2	61.2	96.7	55.8
2008	47	45.3	6.4	51.7	46.9	95.7	53.6
2009	52	72.9	8.6	81.5	74.2	86.5	62.1
All years	210	59.9	11.8	71.7	65.1	92.9	56.9
	Leinster						
Year	n completed surveys	mean sure	mean unsure	all	All (max 48 per spot)	% surveys with bats	% spots with bats
2006	102	43.9	27.2	71.2	51.1	94.1	61.1
2007	195	37.6	6.9	44.4	43.6	89.7	55.6
2008	135	33.4	5.6	39.0	38.0	85.9	52.9
2009	168	37.7	7.8	45.4	44.4	90.9	55.2
All years	600	37.7	10.3	48.0	43.8	89.9	55.8
	Munster						
Year	n completed surveys	mean sure	mean unsure	all	All (max 48 per spot)	% surveys with bats	% spots with bats
2006	64	47.0	13.8	60.8	58.0	95.2	61.6
2007	80	48.4	7.3	55.7	52.1	90.0	50.7
2008	68	39.3	7.6	46.8	42.9	91.2	49.7
2009	80	42.3	6.8	49.1	44.3	89.5	46.2
All years	292	44.3	8.7	53.0	49.2	91.3	51.7
	Ulster						
Year	n completed surveys	mean sure	mean unsure	all	All (max 48 per spot)	% surveys with bats	% spots with bats
2006	35	32.1	16.9	49.0	48.4	88.6	53.7
2007	51	29.8	8.7	38.5	37.6	96.1	57.1
2008	61	39.8	9.9	49.7	48.7	96.7	56.9
2009	79	44.1	9.9	53.9	51.5	94.9	60.3
All years	226	37.8	10.7	48.5	47.1	94.7	57.6
	All Ireland						
Year	n completed surveys	mean sure	mean unsure	all	All (max 48 per spot)	% surveys with bats	% spots with bats
2006	252	47.6	21.3	68.8	57.8	93.2	59.1
2007	386	41.5	7.7	49.2	47.3	91.7	54.8
2008	311	37.7	7.0	44.7	42.5	90.7	53.1
2009	379	45.1	8.1	53.3	50.2	90.9	55.3
All years	1328	42.8	10.3	53.0	49.0	91.5	55.4

Table A2.3: Effects of factors from the REML model.

Ordinary means and standard errors are shown for numbers of Daubenton's bat 'passes' (Sures and Unsures), as well as predicted values on the log scale, after adjusting for the effects of other factors in the model. The number of surveys is for the raw means; adjusted means are sometimes based on fewer surveys due to missing values amongst the covariates.

(a) Width (F = 21.56 with 1 and 536 d.f., P<0.001, fitting as linear on the log-scale)

		Raw data		Adjusted for other variables	
Group	surveys	mean count	s.e.	log	s.e.
2m or less	15	9.3	3.79	0.193	0.130
<=5m	375	32.2	2.29	0.372	0.028
<=10m	495	60.2	3.43	0.468	0.025
<=20m	256	67.7	7.86	0.457	0.031
>20m	149	61.0	4.80	0.581	0.045

(b) Temperature (F = 6.29 with 1 and 822 d.f., P=0.012)

		Raw data		Adjusted for other variables	
Group	surveys	mean count	s.e.	log	s.e.
<=12C	282	45.0	3.48	0.422	0.024
12.1-14	319	56.3	6.34	0.453	0.023
14.1-16	356	56.7	3.89	0.450	0.023
16.1-18	181	45.9	3.70	0.460	0.026
over 18C	56	60.9	11.52	0.512	0.037

(c) ID skills (F = 2.77 with 3 and 420 d.f., P=0.041)

		Raw data		Adjusted for other variables	
Group	surveys	mean count	s.e.	log	s.e.
Poor	105	42.5	5.47	0.405	0.040
Okay	622	43.5	2.03	0.413	0.021
Good	425	62.1	3.83	0.473	0.025
Very Good	146	75.8	13.25	0.506	0.042

(d) Minutes after sundown (F= 7.40 with 1 and 816 d.f., P=0.007 as a linear term)

		Raw data		Adjusted for other variables	
Group	surveys	mean count	s.e.	log	s.e.
before 30 mins	73	47.0	7.38	0.443	0.033
30-40mins	309	50.8	3.57	0.448	0.023
40-50mins	548	57.5	4.40	0.440	0.022
50-70mins	189	50.6	4.27	0.470	0.026
70-90mins	53	46.2	5.82	0.504	0.037

(e) Time taken (F = 5.94 with 1 and 946 d.f., P=0.015, fitting as linear on the log-scale)

		Raw data		Adjusted for other variables	
Group	surveys	mean count	s.e.	log	s.e.
<=60min	199	40.9	4.47	0.397	0.028
61-75min	400	53.9	3.20	0.452	0.023
76-90min	344	61.4	6.33	0.460	0.023
over 90min	189	51.2	3.48	0.470	0.028

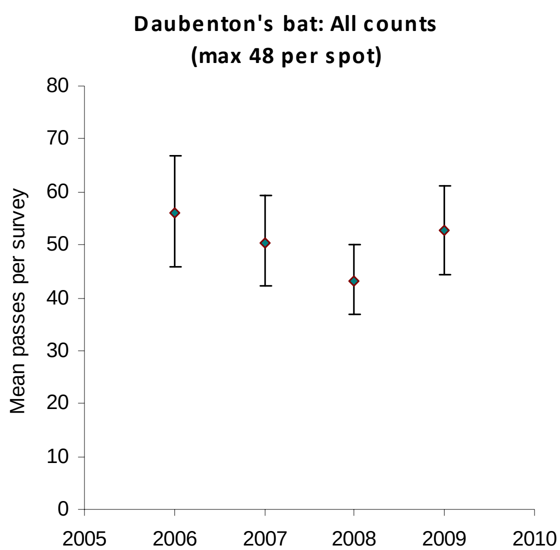
(f) Detector group (F = 2.54 with 4 and 520 d.f., P=0.039)

		Raw data		Adjusted for other variables	
Group	surveys	mean count	s.e.	log	s.e.
Magenta Mk III	227	54.0	4.15	0.471	0.033
Bat Box III	374	55.4	3.24	0.454	0.027
Pettersson D100	126	28.5	2.96	0.395	0.044
Duet	115	77.3	16.45	0.517	0.042
others	459	51.3	3.30	0.409	0.024

Table A2.4: Variables tested and found to be non-significant when added to REML model.

Term	F	d.f. 1	d.f. 2	P
province	0.67	3	292	0.569
east	0.00	1	294	0.988
north	0.04	1	294	0.841
cloud	2.54	3	756	0.055
wind	0.34	3	751	0.797
rain	2.29	3	788	0.077
date	0.45	1	563	0.501
period	0.33	1	506	0.565
week	0.87	5	674	0.499
tree shelter	0.69	3	316	0.556
smooth water	2.01	3	481	0.112
clear	1.37	1	572	0.243
experience	0.05	3	451	0.987

Figure A2.1: Results of the GLM for total number of bat 'passes' (All bat 'passes' = 'Sure' Daubenton's bat 'passes' and 'Unsure' Daubenton's bat 'passes') and for total number of 'Sure' Daubenton's bat 'passes' only. Bars are 95% bootstrapped confidence limits.



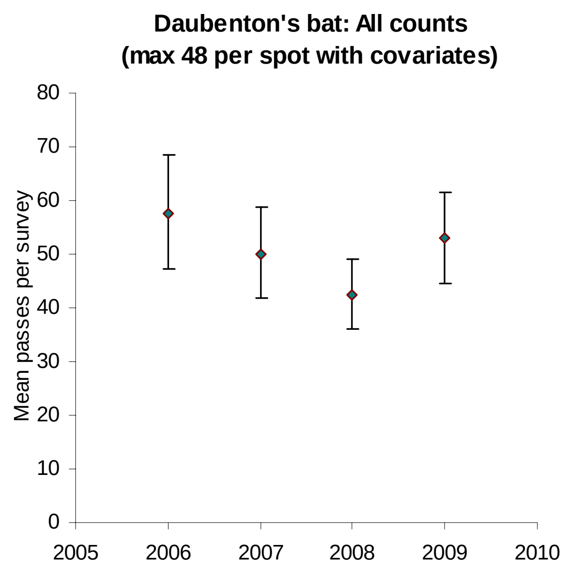


Table A2.5: Binomial GAM results with 95% confidence limits. Note that the proportions of spots with bats are slightly different to those shown in Table 1 since these results exclude sites only surveyed in a single year, which contribute no information on trends.

a) No covariates

			Prop'n spots with bats		Proportion estimated from model					
					Smoothed trend		95% conf limits		unsmoothed	
year	**counts**	**sites**	**Mean**	**s.e.**	**estimate**	**s.e.**	**lower**	**upper**	**fitted**	**s.e.**
2006	218	113	0.601	0.010	0.610	0.024	0.561	0.655	0.615	0.025
2007	300	156	0.573	0.009	0.568	0.019	0.530	0.606	0.577	0.022
2008	289	164	0.535	0.009	0.536	0.019	0.499	0.574	0.525	0.022
2009	285	161	0.555	0.009	0.540	0.022	0.499	0.580	0.550	0.022

Total sites: 204

b) With covariates for smooth water, time after sunset, temperature and log time

			Prop'n spots with bats		Proportion estimated from model					
					Smoothed trend		95% conf limits		unsmoothed	
year	**counts**	**sites**	**Mean**	**s.e.**	**estimate**	**s.e.**	**lower**	**upper**	**fitted**	**s.e.**
2006	172	94	0.594	0.012	0.607	0.027	0.552	0.657	0.616	0.029
2007	238	134	0.596	0.010	0.584	0.021	0.541	0.625	0.594	0.024
2008	246	144	0.539	0.010	0.568	0.022	0.523	0.611	0.567	0.027
2009	239	140	0.546	0.010	0.569	0.025	0.519	0.617	0.580	0.026

Total sites: 198

Table A2.6: Effects of factors from the REML model. Ordinary means and standard errors are shown for numbers of passes (Sures and Unsures), as well as predicted values on the log scale, after adjusting for the effects of other factors in the model. The number of surveys is for the raw means; adjusted means are sometimes based on fewer surveys due to missing values amongst the covariates.

(a) Rain – daily total from met stations (F = 8.26 with 1 and 659 d.f., P=0.004, fitting as a linear term)

		Raw data		Adjusted for other variables	
Group	surveys	mean count	s.e.	log	s.e.
<0.5mm	314	55.2	4.77	0.461	0.024
<2mm	440	51.4	3.10	0.458	0.023
<5mm	241	63.9	7.87	0.448	0.025
5mm+	227	43.0	3.31	0.411	0.025

APPENDIX 3

Brown long-eared Roost Monitoring

Table A3.1: Results of roosts monitored in 2009 displaying Emergence Dusk Counts and Internal Counts

		S1	*S2*	*S3*
All surveys	Total no. of bats	559	420	893
	No. of roosts	25	18	32
	Mean	22.36	23.33	27.91
	S.D.	13.27	19.86	17.69
Emergence dusk counts	Total no. of bats	336	368	620
	No. of roosts	15	14	25
	Mean	22.4	26.29	24.8
	S.D.	12.41	21.33	14.84
Internal counts	Total no. of bats	223	52	273
	No. of roosts	10	4	7
	Mean	22.3	13	39
	S.D.	15.17	8.907	23.48

Table A3.2: GLM results with 95% confidence limits

							95% conf limits	
year	**counts**	**sites**	**Mean**	**s.e.**	**estimate**	**s.e.**	**lower**	**upper**
2007	24	15	18.7	2.3	19.9	2.6	15.5	26.0
2008	51	30	18.5	2.3	18.9	2.6	14.1	24.1
2009	51	25	23.2	2.5	22.0	3.4	15.5	28.8

Total sites: 30

Figure A3.1: Histograms of brown long-eared bat counts. 2007 is at the top (a), 2008 in the middle (b), 2009 at the bottom (c). The vertical axis represents the number of surveys in each size group.