All Ireland Daubenton's Bat Waterway Monitoring Scheme 2006-2011

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All Ireland Daubenton's Bat Waterway Monitoring Scheme 2006-2011

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Executive Summary

All bat populations are protected under Irish legislation. Under EU legislation Ireland is further required to maintain bat populations at favourable conservation status and to conduct monitoring programmes to assess bat population trends. Bat population trends provide an indication of ecosystem health.

The Daubenton's bat is a suitable bat species for new volunteers to survey. It is easy to see when foraging because it feeds close to the water surface, typically within 30cm of smooth water. It forages over waterbodies such as rivers, wide streams, canals, ponds and lakes. In addition, the characteristic nature of Daubenton's bats flying along a regular 'beat' over the surface of water makes it an easy species to survey.

Using the monitoring methodology developed by Bat Conservation Trust (BCT), UK, Daubenton's Bat Waterway Survey (DBWS) was introduced through the Republic of Ireland and Northern Ireland in 2006. From 2006-2011, the scheme was managed by Bat Conservation Ireland and was jointly funded by the National Parks and Wildlife Service (NPWS) (RoI) and the Northern Ireland Environment Agency (NIEA).

The number of waterway sites surveyed annually has increased since the scheme was first introduced. In 2006, 134 waterway sites were surveyed increasing to 224 waterway sites in 2011. Overall, 422 waterway sites have been surveyed at least once over the six years of the scheme providing an excellent, robust dataset on the distribution of Daubenton's bats across the island. Sixty-seven waterway sites were located in Northern Ireland while 355 waterway sites were located in the Republic of Ireland. During the six years of monitoring, Daubenton's bat passes were recorded on 385 waterway sites (91.2%). The mean number of 'Sure' Daubenton's bat passes recorded for all six years was 46.4 per survey with the highest mean recorded in 2011.

This monitoring scheme is dependent on volunteers to survey local waterway sites. While 467 survey teams have participated in the scheme to-date there is a high turnover of survey teams with approximately 40 new survey teams recruited annually. Only 45 survey teams have participated for all six years of the monitoring scheme.

An array of variables was tested and a total of six had a significant influence on the proportion of survey spots with Daubenton's bat: waterway site width; presence of street lights; air temperature at the start of the survey; surveys being completed on dry nights and timing of survey. Daubenton's are more likely to be present in wider river corridors (to a max of 20m wide), at survey spots with trees and hedgerows, on warm dry nights and if the survey does not take place too soon after sundown. In contrast, the presence of street lights causes a reduction in Daubenton's activity. Water quality is

important. When the Q value is 3 (poor), around 20% fewer survey spots have Daubenton's bats compared to spots with a Q value of 4 (good).

Yearly trend analysis results suggest that there was a decline to 2008 with numbers stabilising in 2009, 2010 and 2011 but changes are quite small relative to the width of the confidence limits and must, therefore, be treated with caution.

Power analysis was carried out to determine the number of waterway sites appropriate to monitor Red and Amber Alert targets. Results show that if between 150 and 200 waterway sites are surveyed each year, it should be possible to detect Red Alerts in 6 years and Amber Alerts in 10 years.

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Introduction

The All Ireland Daubenton's Bat Waterway Monitoring Scheme is a project funded by the National Parks and Wildlife Service (NPWS) of the Department of Arts, Heritage and Gaeltacht, Republic of Ireland and Northern Ireland Environment Agency (NIEA). This scheme aims to be the primary tool for monitoring Daubenton's bats in the Republic of Ireland and Northern Ireland. This monitoring protocol was devised Bat Conservation Trust, UK and introduced in Ireland by Bat Conservation Ireland (BCIreland) in 2006 and has been managed by BCIreland since then.

This report presents a synthesis of results for the first six years (2006-2011) of monitoring in the Republic of Ireland and Northern Ireland and follows earlier reports (2006-2008) produced by BCIreland (e.g. Aughney *et al*. 2009).

Why Monitor Bats in Ireland?

Bats constitute a large proportion of the mammalian biodiversity in Ireland. Nine species of bat are known to be resident on the island of Ireland and form almost one third of Ireland's land mammal fauna. Bats are 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, including the Daubenton's bat (*Myotis daubentonii*), are protected under Irish and EU legislation. Under the Wildlife Act (1976) and Wildlife (Amendment) Act 2000, it is an offence to intentionally harm a bat or disturb its resting place.

The EU Directive (92/43/EEC) on the Conservation of Natural and Semi-natural Habitats and of Wild Flora and Fauna (The Habitats Directive) lists all Irish bat species, including the Daubenton's bat, in Annex IV while the lesser horseshoe bat (*Rhinolophus hipposideros*) is also listed in Annex II. Member states must maintain or restore 'Conservation Status' of species listed in Annex II, IV and V. Favourable conservation status is defined as 'the sum of the influences acting on the species concerned that may affect long-term distribution and abundance'. Article 11 of the Directive requires 'Member States to undertake surveillance of the conservation status of all bat species'.

Ireland is also a signatory to a number of conservation agreements pertaining to bats including the Bern and Bonn Conventions. Under the Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals, 1979), Ireland is a signatory of the European Bats Agreement (EUROBATS). This agreement recognises that bat species can only be fully protected if their migratory range is protected. Under this agreement, strategies for monitoring bat populations of selected species have been reviewed and standardised methodologies have been recommended (Battersby, 2010). Across Europe, the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention 1982), which, in relation to bats, works to conserve all species and their habitats, adds protection to areas outside the EU.

The objectives of the Convention on Biological Diversity are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding. To fulfill international obligations under the Convention on Biological Diversity and Agenda 21 agreed in 1992, Local Biodiversity Plans must be devised. The 1992 global agreement requires signatory parties to "identify components of biodiversity … and monitor, through sampling and other techniques, the components of biological diversity identified" (Article 7).

The first Irish Red Data Book of Vertebrates (Whilde, 1993) listed the populations of all Irish bats species that were known to occur at the time as Internationally Important.

Marnell *et al*. (2009), in the most recent Irish Red List for Terrestrial Mammals, lists the status of most Irish bat species as 'Least Concern' excepting Leisler's bat (*Nyctalus leisleri*) which is ascribed 'Near Threatened' status. Also, Brandt's bat (*Myotis brandtii*), the status of which is unclear in Ireland, is described as 'Data Deficient'.

Scientifically rigorous methods of surveillance and monitoring are essential and require well-planned strategies to achieve statistically defensible results (Battersby, 2010). However, bats are not easy to monitor because they are nocturnal and difficult to identify when flying. In addition, individual species differ in their detectability (using bat detectors) and in their foraging and roosting strategies. Therefore, it is essential that appropriate methods of surveillance and monitoring are undertaken for specific species of bat (Battersby, 2010) and that the most appropriate method is chosen based on a general understanding of the roosting habitats, foraging behaviour, seasonal movements and the influence of environmental factors on local abundance and distribution (Kunz, 2003; Warren & Witter, 2002). Methods used to determine trends in bat populations can include foot-based bat detector surveys (e.g. BCT, 2010), car-based surveys (Roche *et al.*, 2011) or roost counts either at summer roosts (Warren & Witter, 2002; Aughney *et al*, 2012) or hibernacula (Tuttle, 2003).

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; *Pipistrellus pipistrellus* and *P. pygmaeus*) 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 that 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.,* 2009). 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 has since run for a 3-year monitoring period (Aughney *et al.*, 2011). 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 (see Aughney *et al.*, 2011 for details).

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 only. 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. All data collected for Northern Ireland by the All Ireland Daubenton's Bat Waterway Monitoring Scheme, as well as the Car-based Bat Monitoring Scheme, feeds into the BCT's UK reporting mechanisms.

Red & Amber Alerts

Monitoring and surveillance protocols need to be able to inform conservation bodies of the trends of the faunal group being investigated. Population trends are often used to identify species that require conservation measures (Dunn, 2002) and confirming a population decline can be used as a rationale to adopt or implement conservation measures. The degree of population decline is also considered to be a valuable evaluation tool with which to identify wildlife populations in trouble (Dunn, 2002). Many standard measurements of population trends are widely used. Rates of population change are regularly used as indicators of the conservation status of species e.g. the conservation alerts defined by The British Trust for Ornithology (BTO). The BTO has developed Alert Levels based on IUCN-developed criteria for measured population declines. Species are considered of high conservation priority (i.e. Red Alert) if their population declines by 50% or more over a 25-year period. Species are considered of medium conservation priority (i.e. Amber Alert) if there is a decline of 25-49% over 25 years (Marchant *et al.,* 1997). A 50% and 25% decline over 25 years translates into an annual decline of 2.73% or 1.14% respectively. These Alerts are based on evidence of declines that have already occurred or can be predicted to occur based on statistically robust monitoring data that is sensitive enough to meet Alert Levels.

Monitoring data should be of sufficient statistical sensitivity (and better, if possible) to meet these Alert levels. The 2006-2008 Synthesis Report (Aughney *et al.,* 2009) included power analysis to evaluate the number of waterway sites that need to be monitored to detect Red and Amber Alerts. Power Analysis indicated that if 150 to 200 waterway sites were surveyed each year, it should be possible to detect Red Alerts in around 6 years and Amber Alerts in 10 years. Results of Power Analysis also showed that a core of 67-75 waterway sites surveyed twice annually and additional 25-33 sites randomly surveyed each year would suffice to determine Amber Alerts after 15.4 years. However, with six years of data now available, further Power Analysis has been undertaken to assess whether these estimates have changed and trends in Daubenton's bat populations have been investigated further. Under the Habitats Directive, Member States are required to identify species declining at >1% per year. Such a decline would put a species into the "Unfavorable - Bad" category. However, at this early stage in assessment of Daubenton's bat populations, assessing trends to this level of accuracy would not be statistically sound. Therefore, it is more appropriate to use a standard measure of population trends.

How to Monitor Daubenton's Bats?

The All-Ireland Daubenton's Bat Waterway Survey addresses the requirement to monitor the Daubenton's bat and is the focus of this report. The survey methodology used for any monitoring scheme is influenced by the ecological and morphological factors in relation to the specific bats species being targeted.

Echolocation calls and bat detectors

Bats are nocturnal mammals becoming active around dusk. Bats emit ultrasonic pulses and navigate in their environment by listening to the returning echoes (Russ, 1999). Each bat species produces different types of bat echolocation calls that are determined by the habitat, morphology of the bat and size of insect prey.

Daubenton's bats tend to use frequency modulated (FM) echolocation sound pulses ranging in a downward sweep with an average frequency range from 79kHz to 33kHz when flying in a typical foraging habitat (e.g. over smooth water). FM echolocation pulses are typically used by bats to determine fine detail in cluttered environments (Russ, 1999).

Many bat monitoring schemes (e.g. Anon, 2009; Roche *et al.*, 2011) rely on the use of bat detectors to identify the characteristic echolocation calls of a particular bat species. Bat detectors convert the echolocation calls of bats into sounds that are audible to humans (Elliott, 1998). The echolocation calls of bats tend to be outside the human hearing range because the human ear is sensitive to sound frequencies from approximately 40Hz to 20,000Hz (20kHz). The most commonly used bat detector type is the heterodyne bat detector; others are Frequency Division and Time Expansion.

Heterodyne bat detectors are tuneable detectors which allow the incoming detectable frequency to be set by the observer. The detector functions as follows: the frequency to which the detector is set, is subtracted from the incoming frequency of the detected bat echolocation call. For example, if the detector is tuned to 50kHz and the incoming bat call is at 55kHz then the resultant output sound from the bat detector is at 5kHz (Elliott, 1998). The main advantage of this type of bat detector is that the resultant sound has tonal qualities (e.g. clicks and smacks) and allows the observer to determine pulse repetition rate. These features, combined with other observations such as habitat and flight pattern of the observed bat, will aid identification (Russ, 1999).

To discriminate fully between species, a combination of visual observations in relation to habitat type, bat flight pattern and detector noise output is used. A Daubenton's bat echolocation call on a bat detector can be described as a rapid series of clicks, often likened to the sound of a machine gun. The pulse repetition rate is very fast and very regular and loudest at 45kHz (Russ, 1999).

Sampling the activity of Daubenton's bats along waterways using a heterodyne bat detector is relatively straightforward. The echolocation call is loudest when the detector is tuned to 45kHz. However to distinguish from foraging pipistrelle bats (*Pipistrellus* species) the detector is tuned to 35kHz. At this frequency, the pipistrelle bat echolocation calls lose much of their tonal qualities but the dry 'clicks' characteristic of Daubenton's bats are still clearly audible (Russ, 1999).

'Bat passes', a tool for surveying Daubenton's bats

A bat 'pass' is a sequence of echolocation calls indicating a bat in transit (Fenton, 1970). The 'bat pass' is the unit generally used when surveying for bats. The characteristic nature of Daubenton's bats flying over the surface of water along a regular beat makes it an easy species to record 'bat passes'.

Factors Influencing Activity Levels of Daubenton's bats

There is world-wide concern over the declines of many faunal populations including bats (Battersby, 2010). Reasons for declines in European bats include habitat loss, habitat fragmentation and degradation, declining numbers of insects from both increased insecticide usage and climate change, remedial timber treatment (Mitchell-Jones *et al*, 1989) and direct loss of roosts (e.g. Racey and Stebbings, 1972). In addition, there are many factors that influence, positively or negatively, the activity levels of bats. Such factors include the presence of artificial lighting, water quality, habitat management, foraging habitat quality, roost availability, predation and competition.

Walsh and Harris (1996) identified water bodies and riparian areas as particularly important habitats for bats because such habitats provide foraging and are essential for commuting and roosting (Altringham, 2003). The Daubenton's bat is a specialist of freshwater habitats feeding on insects taken from the surface of waterbodies such as rivers, canals, ponds and lakes (Racey, 1988; Russ & Montgomery, 2002). This species will also often roost close to such waterbodies in mature trees or stone structures (e.g. bridges).

In 2011 Bat Conservation Ireland commissioned the Centre for Irish Bat Research (CIBR) to investigate the landscape conservation needs of Irish bat species. This project, using BCIreland's existing database of records (2000-2009), including the All Ireland Daubenton's Bat Waterway Monitoring Scheme dataset, analysed habitat and landscape associations and identified the geographical areas that are suitable for individual species. The associations that result in these patterns was summarized (Lundy *et al.*, 2011). The 'core favourable area' was identified for Daubenton's bats. The landscape association results for this species reflect its widespread distribution across the island and its high dependence on riparian habitat. Other habitats that were highlighted as important for the species included broadleaf woodland (the species is more likely to be recorded where there is more of this kind of woodland in a 0.5km radius) and low density urban areas. The predicted core range (Figure 1) of the species has a trend toward the central regions of the island which may reflect areas where there is a higher proportion of lakes and slow moving rivers, which this species favours for foraging.

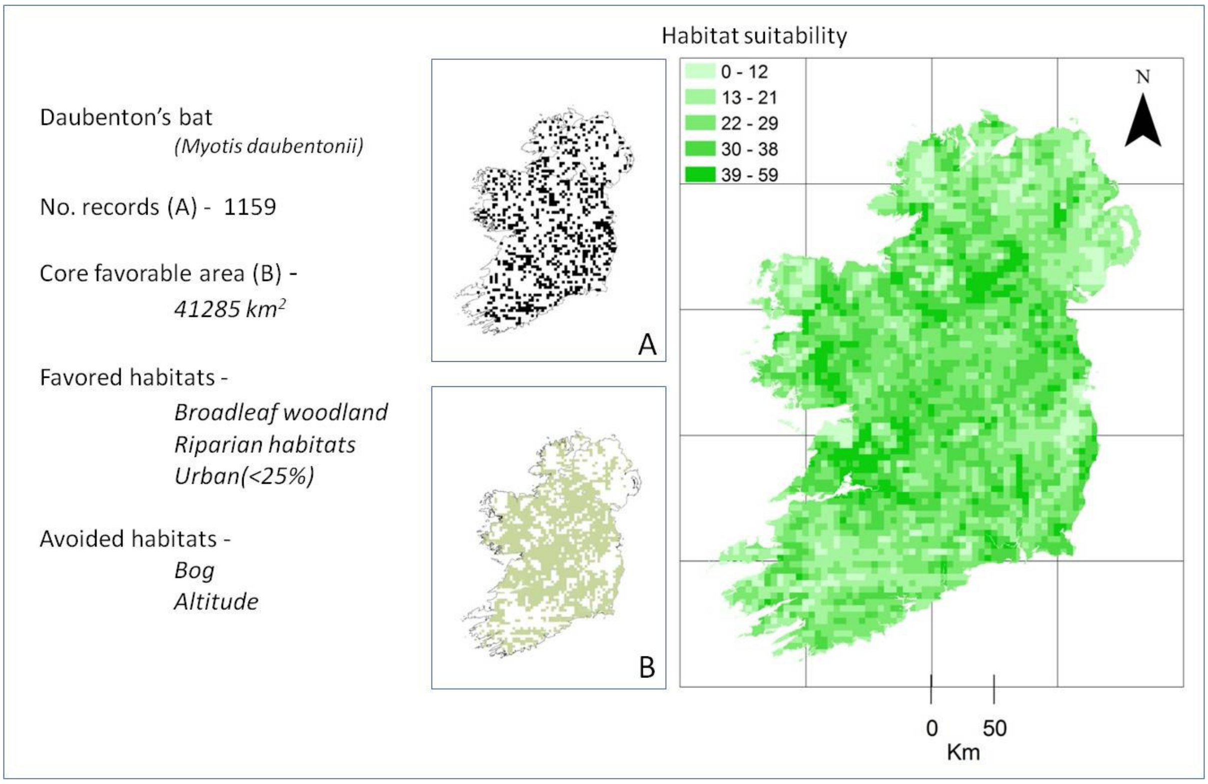


Figure 1: Habitat association summary of Daubenton's bat. Insert A. Shows the distribution of records used to create the landscape model. B. Shows the core area of favourable habitat for the species (Reproduced from Lundy *et al*, 2011).

The localized presence or absence and indeed the level of bat activity of Daubenton's bats on a waterbody may be determined by waterway features such as waterway width, vegetation structure of the riparian zones, water quality and anthropogenic influences such a street lights.

Water Quality

Since the Daubenton's bat is a specialist of freshwater habitats feeding on insects taken from the surface of waterbodies (Racey, 1988; Russ & Montgomery, 2002) it is likely to be affected by changes in water quality and may, therefore, be a potentially valuable indicator of water quality (Jones *et al.*, 2009). The UK National Bat Habitat Survey (Walsh and Harris, 1996) revealed a low preference by bats for rivers in some intensively agricultural areas, possibly due to pollution. This species is widespread in Ireland (Russ & Montgomery, 2002; Aughney *et al.*, 2009) and is the only one of three European 'trawling' species found here. In contrast to many European bat species, the Daubenton's bat has been reported to be increasing across much of Europe (Racey *et al.*, 1998). These increases have been attributed to eutrophication of freshwaters in Europe creating more favourable feeding areas for this species (Kokurewicz, 1995).

Eutrophication, which is the enrichment of water or soil by nutrients, typically compounds containing nitrogen or phosphorus, is recognised as a major threat to freshwater, marine and terrestrial habitats worldwide. In Ireland, the Environmental Protection Agency (EPA) has identified eutrophication as the foremost threat to water quality of Irish rivers and lakes (Toner *et al.,* 2005; Clabby *et al.,* 2008). Nitrogen and phosphorus applications to Irish farmland had increased dramatically between 1950 and 1990 (Tunney *et al.,* 1998). Diffuse run-off of excess nutrients from farmland is likely to be the primary cause of eutrophication of Irish waterbodies while point-source municipal waste-water discharges (e.g. poorly treated sewage effluent) was the most significant cause of moderate and serious river pollution incidences between 2001-2006 (Toner *et al.,* 2006; Clabby *et al.,* 2008). Euthrophication impacts riverine ecology by causing reduced dissolved oxygen levels; this happens because of the respiratory demand of microbes while decomposing the additional organic matter in the water. As a consequence, the freshwater macroinvertebrate communities are altered, with organisms tolerant of such conditions becoming dominant (McGarrigle, 1998). Therefore, the emergent insect populations can be altered with potential impacts on predators such as bats (Vaughan *et al.*, 1996).

Catto *et al*. (2003) and Langton *et al.* (2010) undertook work on the influence of waterway features such as water quality on Daubenton's bat activity in England and Wales. These studies used data collected by The UK's Daubenton's Bat Waterway Survey (DBWS). The DBWS data was combined with data from three datasets: the River Habitat Survey, UK (RHS), which is a method for assessing the character and quality of river stretches based on their physical structure (Raven *et al.,* 1998); General Quality Assessment (GQA), which is an assessment of biological and chemical quality of rivers, and Countryside Survey 2000, a dataset of detailed field observations and satellite imagery captured in 1998 and 1999 to provide a complete land cover census for Great Britain and Northern Ireland. From this analysis, among other things, variables relating to biological water quality were shown to be an important factor influencing the activity level of Daubenton's bats on a waterway. It was found that the number of benthic macroinvertebrate taxa was highly significant in relation to Daubenton's bat activity (Langton *et al.,* 2010), with greater activity along waterways with higher diversity.

However previous studies such as Kokurewicz (1995) and Vaughan *et al.* (1996) have indicated that Daubenton's bats have a preference for euthrophic waters. Vaughan *et al.* (1996) demonstrated that the level of *Myotis* species foraging activity in the UK increased downstream of sewage works. Kokurewicz (1995) ascertained that the expansion of Daubenton's bats across mainland Europe was due to an increase in eutrophication of waterbodies which increased the abundance of pollution-tolerant insects available as prey for bats. In contrast Abbot *et al.* (2009) recorded that Daubenton's bats on Irish rivers investigated were less active downstream of sewage works in comparison to activity levels recorded upstream. Abbot *et al.* (2009) attributed this to Daubenton's bats preference for feeding on Trichoptera (caddis flies) which were significantly more abundant upstream. She concluded that the effects of organic pollution on bat activity may be more complex than previously thought. Sijpe *et al.,* (2004), on the other hand, reported Daubenton's bats hunting over all waterways in Belgium regardless of the pollution level.

The selection of waterway sites for the All Ireland Daubenton's Bat Waterway Monitoring Scheme, where possible, corresponded to current water quality sampling sites monitored by the Environmental Protection Agency, Republic of Ireland and the Water Management Unit, NIEA, Northern Ireland. The biological water quality index for All Ireland Daubenton's Bat Waterway Monitoring Scheme waterway sites has been collated to investigate if there is any impact of water quality on the level of Daubenton's bat activity on waterways across Ireland.

Invertebrates are most commonly used as indicators because they comprise a large proportion of terrestrial and aquatic species richness, are often habitat specialists and are sensitive to small scale changes.

In the Republic of Ireland, the Environmental Protection Agency (EPA) undertakes water quality sampling while in Northern Ireland, the NIEA is charged with this function. Much of the measures used to determine water quality status of rivers is determined by meeting the requirements of the Water Framework Directive (WFD). The WFD specifies that the water quality status of rivers should be determined by a combination of biological, chemical and physio-chemical elements. McGarrigle *et al.* (2010) reviewed the current status of rivers in Ireland. In the period 2007-2009 13,188km of rivers were sampled. Under the WFD there are five pollution status classifications: High status = unpolluted; Good status = unpolluted; Moderate status = slight pollution; Poor status = moderate pollution and Bad status = serious pollution. The current status of rivers in the RoI is as follows: High status: 20.1%; Good status: 48.8%; Moderate status: 20.7%; Poor status: 10% and Bad status: 0.4% (McGarrigle *et al.,* 2010).

The Biotic Index (Q value system) that the EPA uses to report its water quality gives an indication of the water quality of a river and this is linked to the community diversity recorded at sampling sites. For example, a Q value 5 is the highest water quality category and means the river is of good water quality and that there is a 'high' community diversity in relation to sampled macroinvertebrates and fish diversity. For the purpose of the macroinvertebrate assessment, benthic macroinvertebrates are divided into five arbitrary 'Indicator Groups' as follows: Group A: the sensitive forms; Group B: the less sensitive forms; Group C: the tolerant forms; Group D: the very tolerant forms and Group E: the most tolerant forms. Changes brought about by organic pollution on macroinvertebrate community have been particularly well documented (Toner *et al.,* 2005; Clabby *et al.,* 2008). The immature aquatic stages of aerial insects together with Crustacea, Mollusca, Oligocheata and Hirundea are part of the 'Indicator Groups'. It is known that the macroinvertebrate community diversity declines in the presence of pollution and that the sensitive species are progressively replaced by more tolerant species as pollution increases.

Riparian habitat structure

Riparian habitats are complex ecosystems that provide a mosaic of patches and habitats that support highly complex invertebrate communities (Malmqvist, 2002). Vegetation structure and prey availability of the riparian zone are known to influence habitat selection by bats (Fenton, 1990). The distribution of invertebrates in riverine habitats is influenced by an array of factors from climate, physical and chemical characteristics of the catchment to small-scale influences of local predation risk, river substrate, riverine vegetation and water velocity. Since bats are highly mobile they can exploit large areas of the landscape. But structural features therein often influence bats' activity levels. In relation to riparian zones, such structural traits can include the extent of tree cover, hedgerows and tall riverside vegetation (Altringham, 2003). Because Daubenton's bats exploit the area just above the surface of the water for feeding, it means that their potential foraging area is relatively restricted (Middleton, 2006). As a consequence, Daubenton's bats often appear to be dispersed along the rivers with the number of bats feeding along a particular stretch of river or canal reflective of its width. It is therefore important to identify if the vegetation structure of each survey spot influences the degree of bat activity of the waterway site being surveyed. Such details could also provide management information for organisations charged with taking care of riparian zones (e.g. OPW in relation to drainage works).

Street lighting along riparian zones

Rydell (1992) showed that the brown long-eared bat avoided feeding in places with artificial lights. Stone *et al.* (2009) also demonstrated that lesser horseshoe bats commenced their activity significantly later on nights where known commuting routes were lit with street lights.

Riparian zones are essentially linear landscape features and are vital for commuting and foraging bats. However, reliance on such linear features makes bats vulnerable to habitat fragmentation. Street lights along such linear landscape features may fragment these habitats for bat usage causing bats to alter their commuting and foraging behaviour.

As urbanisation expands into the landscape, the degree of street lighting also expands. As a consequence, habitat loss or degradation and its monitoring become increasingly important. As almost all bats are nocturnal mammals, they are ideal subjects for testing the effects of light pollution (Stone *et* *al.*, 2009). Stone *et al.* (2009) state that commuting bats may respond to light disturbance in four ways: flying high above or around lights; flying to unlit sides of the linear habitat; choosing an alternative route or returning to the roost. Lundy *et al.* (2011), as previously mentioned, showed that the Daubenton's bat can tolerate low density urbanisation but it is important to demonstrate clearly if there is an impact on bat activity from increased street lighting. Rivers or canals flowing through urban areas often provide an important dark zone for commuting wildlife. The presence or absence of Daubenton's bats along urban waterways may be an indication of light pollution causing ecosystem fragmentation, and therefore, using this species as a reference point may underline, for local and waterways authorities, the extent of habitat damage from street lighting.

Weather & Climate change

Studies have shown that flight activity of bats is affected by day to day weather conditions and, in general, increased bat activity has been noted with increased temperature (e.g. Catto et *al*. 1995; Negraeff and Brigham 1995). Rainfall has also been found to affect bat activity with some species reluctant to fly in heavy rain (Erkert 1982).

On a global scale questions surrounding the impact of weather conditions on bat populations have become increasingly important. The planet is currently undergoing human-induced climate change on an unprecedented scale. Air temperature changes as a result of global warming have been shown to be advancing life cycle events in animals and plant species (Thackeray *et al.,* 2010). Monitoring such impacts requires bio-indicator taxa that show measurable responses to climate change and resultant habitat loss. Jones *et al. (*2009) suggest that bats have an enormous potential as bio-indicators because of their taxonomic stability, trends in their populations can be monitored, short- and long-term effects on populations can be measured and they are widely distributed around the planet. Consequently they urge that a global network for monitoring bat populations should be established.

Climate change manifests its influence on biota as a result of altered patterns of rainfall and temperatures. This coupled with habitat conversion (natural habitats converted to managed habitats) may threaten the long-term existence of many plant and animal species. Therefore, it is important that any monitoring schemes of global climate and habitat changes capture local, regional and global components. Jones *et al. (*2009) argue that bats are suitable candidates to achieve this since some of the major stresses that have an impact on biodiversity in general also have major impacts on bat populations.

While the Daubenton's bat global distribution is along a narrow band across Asia and Europe, Ireland does represent the most westerly point in its range. Rebelo *et al.* (2009) predicted range changes of 28 species of bat in Europe (grouped according to their biogeographic patterns) with a variety of IPCC climate change scenarios. Daubenton's bat was assigned to the Temperate group and, while it was predicted to show a slight increase for the present decade, Rebelo *et al.* forecast a decrease in the extent of its European range for the remainder of the century was forecasted in all modeled climate change scenarios.

Temperatures in Ireland have increased in line with global increases and climate change has already been shown by O'Neill *et al.* (2012) to be advancing the phenology of moth species in Ireland. It is likely that other insect species considered to be important prey items for bats are also being affected by climate change. O'Neill *et al.* (2012) have shown that while moths in Ireland exhibited phenological changes, these changes varied according to their locations on the island. Moth species in County Donegal exhibited shorter flight periods in comparison to the flight periods of similar species in County Cork. Climate change is considered to have a more latitudinal impact on plant and animal life cycles (Both and te Marvelde, 2007) and, therefore, monitoring the activity levels of Daubenton's bats across its distribution on the island (south to north distribution) may further our understanding of the effects of climate change in Ireland.

The aims of this report

This is the second synthesis report for the All Ireland Daubenton's Bat Waterway Monitoring Scheme. For more detail on previous years of the scheme see Aughney *et al*. (2009) and the Irish Bat Monitoring and Recording Schemes Annual Reports (e.g. Aughney & Roche, 2008; and Aughney *et al*., 2010) available at www.batconservationireland.org/pubs/reports

This report synthesises the data collected from 2006-2011 and

1. Examines volunteer participation, time and effort and geographical coverage
2. Reviews total bat encounters, by year and by province
3. Looks at population trend data
4. Revisits Power, to detect both Alert level decreases or population increases
5. Examines the data in relation to waterway characteristics, street lighting, air temperature and water quality
6. Makes recommendations on the future of the monitoring scheme.

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).

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).

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).

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. Volunteers are required to survey in pairs for safety reasons. One member of the team is designated as Surveyor 1 and uses the bat detector and torch while Surveyor 2 documents the number of bat passes and other information required for the recording sheets (Appendix III). Information on the bat detection skills of Surveyor 1 and model of bat detector is requested for incorporation into analyses. On completion of both nights, surveyors are requested to return completed recording sheets and map (with the ten survey spots marked out) to BCIreland for analysis and reporting.

Volunteer uptake and participation

The All Ireland Daubenton's Bat Waterway Monitoring Scheme relies on the participation of volunteers to survey the large number of waterway sites required to meet Red and Amber Alerts. A recruitment drive is undertaken annually. An on-line registration system was set up on the BCIreland website to facilitate volunteer participation. BCIreland also works closely with Heritage Officers and Biodiversity Officers in county councils to facilitate their local volunteer network.

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 a detailed description of the methodology, maps, survey forms and online training details are provided for each survey team. Heterodyne bat detectors are also available on loan for the duration of the summer months.

Volunteers receive regular updates and two newsletters per year on the progress of the monitoring scheme.

Influencing Factors – New Parameters

The following additional information was recorded by survey teams, or derived from national authorities such as the EPA, to supplement our knowledge of factors that may influence the activity levels of Daubenton's bats along monitored waterways. This is in addition to data collected on waterway features (e.g. waterway width) by survey teams as standard since the onset of the monitoring scheme.

Water Quality

Water quality data was collated from the EPA and NIEA for waterways sites surveyed between 2006–2011. Biological water quality data was collected for water quality stations within a 1km radius of the waterway site start point. Water quality data collected from the EPA with regards to rivers in the Republic of Ireland was taken primarily from the 2006-2011 monitoring period. Some additional data was used from 2000-2005 water quality data and pre-2000 for a limited number of sites that were not sampled for water quality in 2006-2011 monitoring period. All data used from the NIEA dataset refers to 2005-2011 results, however, due to the different way it measures biological data compared to the larger dataset from the EPA, the NIEA dataset was excluded from analysis.

In relation to statistical analysis two measures of Daubenton's activity were used against water quality;

- A simple mean of counts per survey, using a maximum of 48 passes per spot
- Site effects from a binomial GLMM of presence at each spot. These measure the probability of observing bats, relative to that expected, given the covariates for the site and survey.

Where possible we used the data sets from the Republic of Ireland and Northern Ireland, but this was not possible for the biological data or for some of the chemical variables where there was no obvious match.

Riparian habitat structure

Additional information with regards to the presence or absence of trees; hedgerows and tall vegetation categories at each survey spots was collected by survey teams since 2009. This was collated in 2011 for analysis. The data collected was in addition to data already being collected since the start of the scheme about whether there are trees present along the length of the transect (three categories).

Street lighting along riparian zones

Additional information with regards to the presence or absence of street lights at survey spots was collected by survey teams since 2009. This was collated in 2011 for analysis.

Statistical Analysis

Bat Passes (counts) versus Binomial

For statistical analysis a log-transformation was carried out on data at the ten individual points within each survey; this effectively calculates the mean of passes for the survey and helps to reduce the influence of the very high counts sometimes recorded due to one or two bats repeatedly passing the observation point. In previous years bat pass counts were used in a REML model (log-transformed) to investigate the potential relationships with collected variables. Since 2010, the dataset (2006-2011) was entered into a model looking at the impact of the various covariates on the probability of observing bats at a spot i.e. a binomial model (Binomial GLMM/GAM model).

Data Included

Analyses were based on data collated on survey dates between day numbers 205-250 (i.e. 24th July and 7th September, if not a leap year) which is designed to give approximately one week either side of the official survey period to maximise the amount of data available. As a consequence, the majority of submitted surveys are included in the model as only a few surveys from the second week in September are excluded.

For analysis based on bat passes, both counts excluding and including 'Unsure' Daubenton's bat passes were used. For binomial analyses, the presence of both 'Sure' and 'Unsure' Daubenton's bat passes at each spot were used. Surveys where no bat passes were recorded are also included in the analysis.

Relationship between Daubenton's and other factors

In 2010, a GLMM analysis was completed to determine the relationship between the proportion of spots with bat passes, at survey level, and listed variables. As it is unlikely that very much will have changed with just one year's extra data, this analysis was not repeated for the 2006-2011 data set but will be reported for the 2006-2010 dataset only. This model contained terms for waterway width, air temperature, identification skills of volunteers, start time, duration of survey and percentage of smooth surface of waterway. Another binomial GLMM model, for the 2011 dataset only, was fitted at survey spot level using additional information collected on vegetation structure at survey spots and the presence/absence of street lights at survey spots.

In addition, data from met stations from Met Eireann in the Republic of Ireland were compared to data recorded by surveyors in the 2010 analysis (2006-2010 dataset) to determine whether data used from such stations proved more beneficial than using weather data collated by volunteer surveyors. This met data from climatological stations was added to the binomial model at survey level. For each survey site the distance to each met station was calculated and 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.

Trends

To assess trends, a Generalised Linear Model (GLM) with a Poisson error distribution (see Glossary) is applied to the entire dataset (i.e. 2006-2011). Confidence intervals are generated by bootstrapping at waterway site level (Fewster *et al*., 2000, see Glossary). The maximum number of bat passes per survey spot used for analysis is 48 passes (both Sure and Unsure) (i.e. one pass per 5 seconds) because it is considered that volunteers differ greatly in how they record continuous activity and this truncation reduces the uncertainty associated with higher counts. This approach is similar to the approach used for assessing trend in Britain in the National Bat Monitoring Programme (NBMP) undertaken by Bat Conservation Trust (BCT, UK), and also for trends in bird populations. Recent work for the NBMP has suggested that precision may be improved, at the risk of some bias, by using logistic regression model for the number of observation points with bats present.

As in 2010 analysis, this year, additional trend analysis was carried out with data from 2006-2011 using Binomial (presence/absence) Models (dataset only includes waterway sites surveyed for two or more years as waterway sites surveyed in a single year do not contribute to information on trends i.e. n= 271 waterway sites). This essentially models the percentage of survey spots with bats present at each waterway site (e.g. 0.7 if Daubenton's bats were observed at seven of the ten survey spots). 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 highlight the change in trend) to the results both with and without co-variates to give a general indication of the trend. The co-variates were determined using the binomial GLMM model.

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 (Fewster *et al.*, 2000) are then fitted to the artificial datasets to see how frequently the trends are detected with different numbers of sites and years. The 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. In addition a simulation by doubling of the population over 25 years (i.e. 2.81% increase per year) was completed. All trends are simulated as constant percentage changes, but analysis does not assume that this is known to be the case. The analysis is worked with 90% confidence limits (.e. a one-sided significance test at P=0.05), and 80% power, which is the minimum acceptable, so results should be viewed as the absolute minimum numbers to achieve good results. Power Analysis was completed on data collated since 2006 (2006-2011 dataset) to determine how much sites vary from year to year.

Results

The results of the 2006-2011 dataset are presented below. A more detailed examination of yearly results is available in Annual Reports at www.batconservationireland.org/pubs/reports.

Descriptive Statistics

Volunteer participation from 2006-2011

The number of volunteers participating in the All Ireland Daubenton's Bat Waterway Monitoring Scheme has increased dramatically since 2006. This ranged from a total of 131 survey teams in 2006 to 191 survey teams in 2011. There were a small number of survey teams that surveyed more than one site annually (e.g. in 2011 16 survey teams surveyed a total of 34 waterway sites) but the majority of survey teams surveyed one waterway site. Three survey teams receive remuneration to ensure that a sub-set of core-waterway sites were surveyed annually to increase the robustness of the data set. The number of waterway sites surveyed by these three teams varied from year to year (e.g. in 2011 20 waterway sites were surveyed).

There is a high turnover of survey teams with approximately 40 new survey teams recruited annually. Over the duration of the six years of the scheme, a total of 467 survey teams have participated in the monitoring scheme. Only 45 (9.6%) survey teams have participated for all six years of the monitoring scheme while 142 (30.4%) survey teams have participated continuously since joining the monitoring programme. Excluding the 45 new survey teams recruited in 2011, 154 (32.9%) survey teams have participated for one year only with all remaining teams participating intermittently or participating for at least two years before leaving the programme.

Volunteer recruitment and training 2006-2011

The training schedule for this monitoring scheme consisted of 13-16 evening training courses per year. These training courses were organised in conjunction with Heritage Officers, Biodiversity Officers, NPWS Education Centers, National Parks, local environmental groups and government agencies (NPWS and NIEA staff). These training events have developed as part of the summer calendar events for Heritage Officers and Biodiversity Officers education programmes. Since 2006, a total of 84 training courses have been organized and have provided training for over 1000 people.

Waterway sites surveyed in 2006-2011

A total of 422 waterway sites have been surveyed on the island since 2006 (See appendices for a complete list of waterway sites surveyed). Sixty-seven waterway sites were located in Northern Ireland while 355 waterway sites were located in the Republic of Ireland (Figure 2).

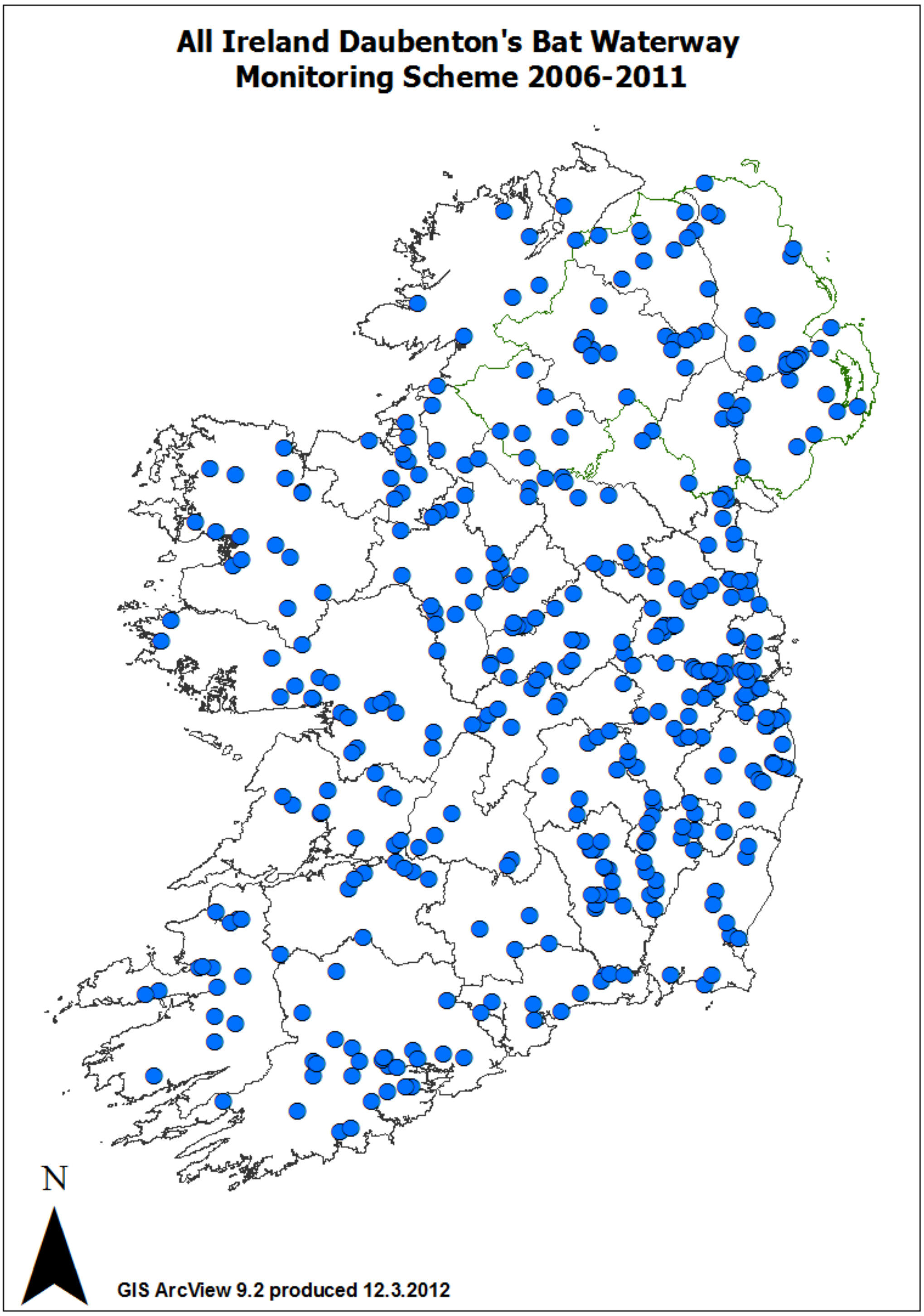


Figure 2: Location of all waterway sites (n=422) surveyed under the All Ireland Daubenton's Bat Waterway Monitoring Scheme (2006-2011).

The highest number of waterway sites was surveyed in 2011 (n=225) (Table 1). The highest number of waterway sites surveyed in each province was in 2011 for Munster (n=47), Connaught (n=33) and Ulster (n=51) and in 2007 for Leinster (n=103).

Table 1: Number of waterway sites (n=422) surveyed in each province over the duration of the All Ireland Daubenton's Bat Waterway Monitoring Scheme (2006-2011)

Column head	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2006-2011**
Connaught	26	31	29	30	28	33	67
Munster	35	42	38	46	40	47	82
Leinster	54	103	76	88	95	94	187
Ulster	19	26	37	44	48	51	86
Northern Ireland	14	20	31	36	36	42	67
Republic of Ireland	120	182	149	172	176	183	355
Total	**134**	**202**	**180**	**208**	**212**	**225**	**422**

* Total number of waterway sites differs from previous reports due to the inclusion of record forms submitted late.

The majority of these waterway sites were located along rivers (n=368, 87.2%) with the remaining waterway sites were located along canals (n=52, 12.3%) and estuarine channels (n=2, 0.5%). A total of 188 rivers, 13 canals and two channels were surveyed. Sixty-four rivers and canals had more than one surveyed waterway site (e.g. 15 waterways sites along the length of the River Boyne).

The greatest number of waterway sites surveyed over the six years were located in the province of Leinster (n=187, 44.3%) (See Table 1 above) while the highest number of waterway sites per county was located in County Cork (n=28, 6.6%) (Figure 3).

Of the 422 waterway sites surveyed, 150 waterway sites (36%) were surveyed in one year only while 45 waterway sites (11%) were surveyed in all six years. The remaining waterway sites (227 waterways sites, 53%) were surveyed from two to five years of the total six year duration of the monitoring programme (Figure 4).

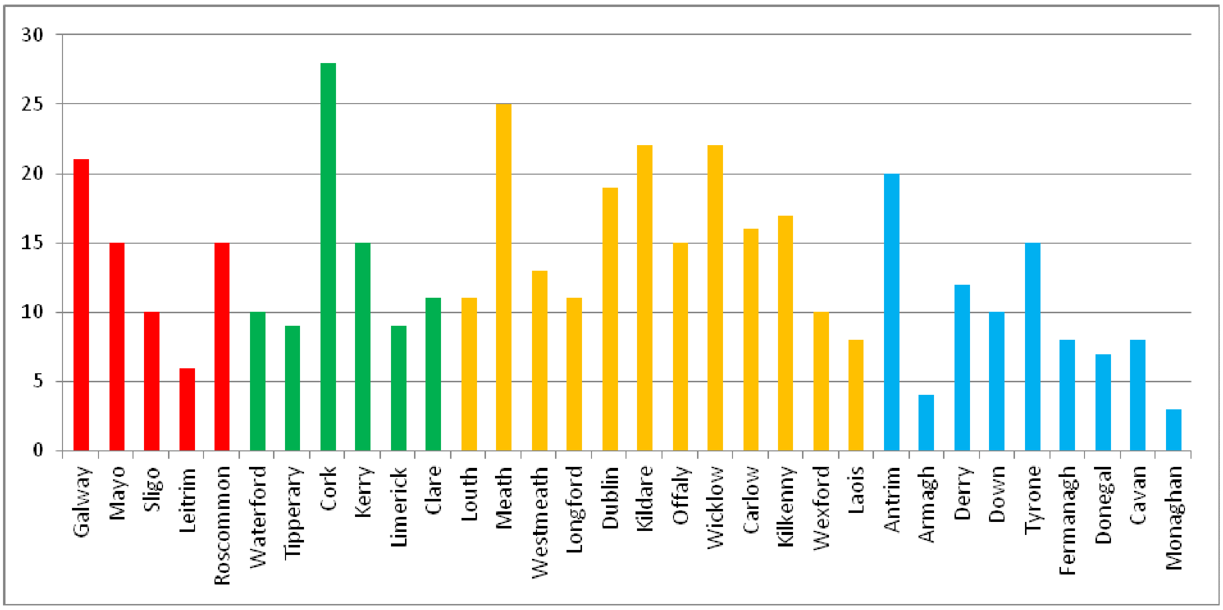


Figure 3: Number of waterway sites surveyed (n=422) in each county (n=32) over the duration of the All Ireland Daubenton's Bat Waterway Monitoring Scheme (2006-2011).

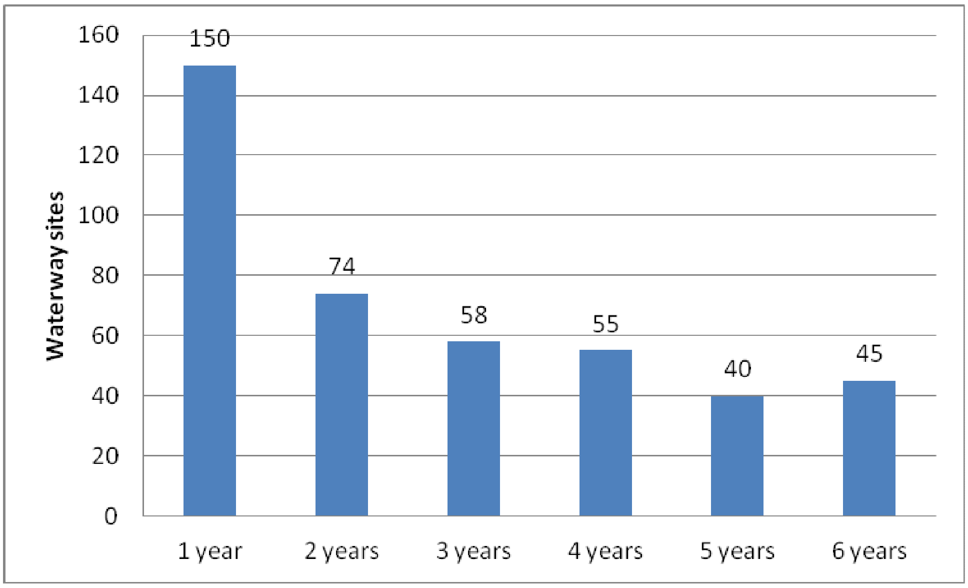


Figure 4: Number of years each waterway site has been surveyed over the duration of the All Ireland Daubenton's Bat Waterway Monitoring Scheme (2006-2011).

Number of completed surveys in 2006-2011

The highest number of surveys was completed in 2010 (n=405 surveys) (Table 2), as distinct from the highest number of waterways which was 225 in 2011 (see above). Overall, 2,140 surveys were completed in the six years of the scheme amounting to 1,426 hours 40 minutes of observation time (four minutes per survey spot, ten survey spots= 40 minutes per survey) and returned to BCIreland. Survey teams were requested to complete two surveys, if possible, per year as this provides more robust data for monitoring. The month of August was split into two sampling periods: Survey 1 (1st August to 15th August) and Survey 2 (16th August to 31st August). Of these completed surveys, 979 were repeat surveys (i.e. Survey 1 and Survey 2 was completed - 91.5%) with the highest number of repeat surveys completed in 2007 (185 repeat surveys, 95.6%).

Table 2: Number of completed surveys (waterway sites n=422) over the duration of the All Ireland Daubenton's Bat Waterway Monitoring Scheme (2006-2011)

Column head	2006	2007	2008	2009	2010	2011	2006-2011
S1 & S2	122	185	133	171	193	175	979
Single survey	12	17	47	37	19	50	182
Total surveys	**256**	**387**	**313**	**379**	**405**	**400**	**2140**

* Total number of waterway sites differs from previous reports due to the inclusion of record forms submitted late.

Number of bat passes recorded in 2006-2011

During the six years of monitoring, Daubenton's bat passes were recorded on 385 waterway sites (91.2%) (Table 3). A higher percentage of waterway sites in Ulster and in Northern Ireland had recorded Daubenton's bat passes: 94.2% and 94% respectively (Figure 5).

Table 3: Number of waterway sites (n=422) surveyed with recorded Daubenton's bat passes in each province over the duration of the All Ireland Daubenton's Bat Waterway Monitoring Scheme (2006-2011)

Column head	2006	2007	2008	2009	2010	2011	2006-2011
Connaught	24	27	28	26	27	30	57 (85.1%)
Munster	33	33	34	39	38	45	75 (91.5%)
Leinster	47	87	61	77	88	88	172 (92%)
Ulster	17	24	36	41	44	47	81 (94.2%)
Northern Ireland	12	19	30	34	31	38	63 (94%)
Republic of Ireland	109	152	129	149	166	172	322 (90.7%)
Total	**121**	**171**	**159**	**183**	**197**	**210**	**385 (91.2%)**

* Total number of waterway sites differs from previous reports due to the inclusion of record forms submitted late.

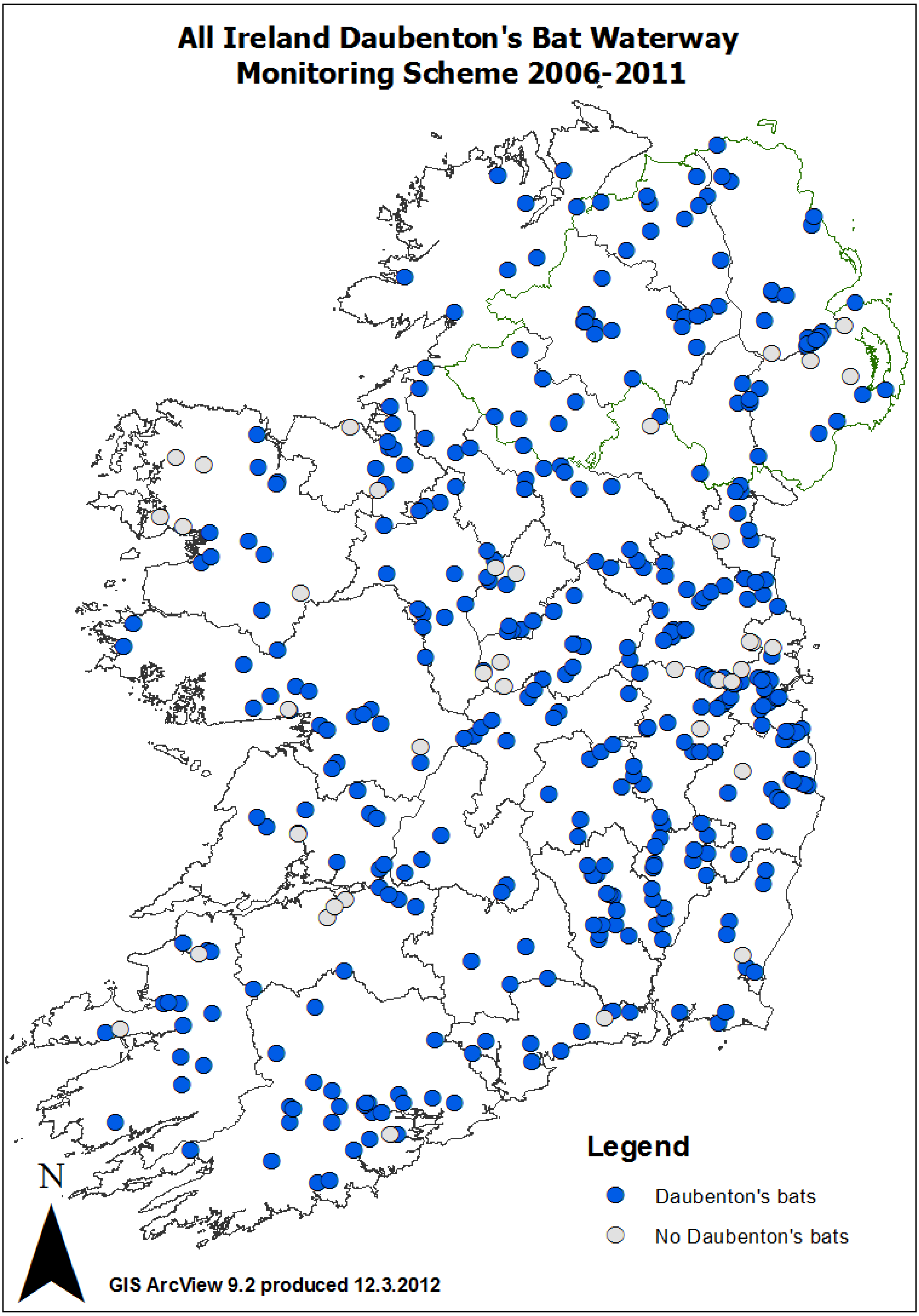


Figure 5: Location of all waterway sites (n=422) surveyed under the All Ireland Daubenton's Bat Waterway Monitoring Scheme (2006-2011) categorised according to presence or absence of Daubenton's bats.

At each of the ten survey spots of each completed survey, survey teams recorded Daubenton's bats (either as 'Sure' or 'Unsure' bat passes) activity for four minutes generating 40 minutes of data per completed survey. In total, 100,152 bat passes were recorded, 77.3% of which were noted as 'Sure' Daubenton's bat passes (Table 4). The proportion of 'Unsure' Daubenton's bat passes was highest in 2006 (33%) when the scheme first started and lowest in 2009 (15%).

Table 4: Number of 'Sure' Daubenton's bat passes and 'Unsure' Daubenton's bat passes recorded (waterway sites n=422) over the duration of the All Ireland Daubenton's Bat Waterway Monitoring Scheme (2006-2011)

Column head	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2006-2011**
Sure Daubenton's bat pass	11,985	15,951	11,735	17,018	20,775	20,828	77,464
Unsure Daubenton's bat pass	5,916	3,971	2,173	2,998	3,731	3,899	22,688
Total number of bat passes	**17,901**	**19,922**	**13,908**	**20,016**	**24,506**	**24,727**	**100,152**

* Total number of waterway sites differs from previous reports due to the inclusion of record forms submitted late.

The mean number of 'Sure' Daubenton's bat passes recorded for all six years was 46.4 per survey with the highest mean recorded in 2011 (52.6 'Sure' Daubenton's bat passes per survey) with the province of Connaught showing a consistently higher mean number of 'Sure' Daubenton's bat passes. A full breakdown of these statistics is presented in Appendix I, Table 1.

Statistical Analysis of Results

Statistical analysis was completed on the dataset summarised in Appendix I, Table 1. Surveys completed outside the date range were excluded from analysis. In addition, one survey form from 2011 was received too late to add to statistical analysis.

Relationship with other variables 2006-2010, survey-level data

To investigate the impact of the various covariates on the probability of observing bats at a spot, a binomial model was applied to the data (2006-2010). This analysis was not repeated on the 2006-2011 dataset as it was considered that one year's extra data would not have changed the overall results.

F-tests rather than χ^2 tests were used, since they accommodate for the structure of the data better. To complete this task, all of the results collated from 2006 to 2010 were included. This dataset is comprised of 1723 completed surveys (2006-2010). However, the number of completed surveys used in the analyses for each variable differs depending on the amount of data noted by volunteers (i.e. missing values).

An array of variables was tested and a total of six variables were found to be significant and these results are presented below (Table 5), while detailed results of these variables are shown in Appendix I, Table 5. Significant terms in the binomial (GLMM) model were similar to those from the REML model (Aughney *et al*., 2010). Where possible, the terms were fitted as linear or quadratic relationships but for ease of presentation, the tables present the continuous variables in categories.

Table 5: Summary of the variables with significant influence on the presence/absences of bat pass at survey spots from binomial GLMM model analysis of the duration of the All Ireland Daubenton's Bat Waterway Monitoring Scheme 2006-2010 dataset

Variable (2006-2010 dataset)	**N completed surveys**	**F-Test**
Width (m)	1465	F = 10.67 with 1 and 529 d.f., P<0.001, for quadratic term
Smooth/calm water	1466	F = 6.06 with 3 and 435 d.f., P<0.001
Minutes after sunset	1397	F = 9.49 with 1 and 950 d.f., P<0.002
Time taken for survey	1295	F = 7.55 with 2 and 1041 d.f., P=0.006
Temperature (^{o}C)	1368	F = 6.288 with 1 and 907 d.f., P<0.0109
Rain (Met Eireann)	1468	F = 10.55 with 1 and 674 d.f., P=0.001

Waterway width values, as estimated by surveyors, were categorised into five groups (from <2m to >20m) and the analysis uses data from 1465 completed surveys (85%). The majority of waterway sites were in the 5m-10m group (n=609). This parameter was found to be highly significant with an upward, quadratic trend (F = 10.67 with 1 and 529 d.f., P<0.001, for quadratic term). As in previous years, width is highly significant, with a higher proportion of survey spots with bats in wider waterways but this effect lessens on very wide rivers (i.e. >20m).

Volunteers are also requested to estimate the percentage of smooth water along the length of their survey transect. There are three categories available to volunteers to tick. A total of 1466 completed surveys (85%) were used in analyses. In previous years, smooth water was not found to have a significant influence on the number of bat passes recorded at survey spots. However, the percentage area of smooth water has a very strong relationship with the proportion of survey spots with bats (F = 6.06 with 3 and 435 d.f., P<0.001). The proportion of survey spots with bats was greater for the 'greater than 50%' smooth water category.

Air temperature was recorded by surveyors at the start of the survey night. The values recorded were grouped into five categories (e.g. <12°C; 12.1-14.0°C, etc). A total of 1368 completed surveys (79%) were used for analyses. Temperature is significant, as in previous years (F = 6.288 with 1 and 907 d.f., P<0.0109). The proportion of survey spots with bats was highest for the temperature category of 'over 18°C'.

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. A total of 1321 completed surveys (77%) were used in analyses. 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 = 9.49 with 1 and 950 d.f., P<0.002) using adjusted means; i.e. an increase in the proportion of survey spots with bats with later start times. When unadjusted means are examined, the number of bat passes recorded by starting too early (e.g. before 30 minutes after sundown) yielded a lower mean number of the proportion of survey spots with bats. This fits with the observation that there tend to be fewer Daubenton's bats, on average, at the first couple of survey spots.

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. A total of 1295 completed surveys (75%) was used in analyses. Time taken to complete surveys, as in previous years, was a significant influence on the number of bat passes recorded. This is also true for the proportion of survey spots with bats (F = 7.55 with 2 and 1041 d.f., P=0.006). Significantly fewer survey spots with bats were recorded for 'fast' surveys (completed in less than 60 minutes) compared to surveys completed 'slow' surveys (>60 minutes).

The relationships between bats and weather variables recorded by the surveyors or data derived from Met Éireann in the Republic of Ireland were also investigated. A total of 1386 completed surveys (80%) were used in analyses (2006-2010). The temperature data recorded by surveyors fits better than the temperature data from met stations and therefore air temperature recorded by volunteers was used. The Met Éireann rain data with this data being highly significant with a lower proportion of survey spots with bats on rainy days (F = 10.55 with 1 and 674 d.f., P=0.001).

Relationship with other variables, 2011 spot-level data

To investigate the potential relationship with variables such as the presence of street lights and riparian vegetation structure (i.e. presence or absence of trees, hedgerows and tall vegetation at each survey spot), the data was fitted to a spot level binomial GLMM model. This was applied to the 2011 dataset only. In addition, site-level covariates (width etc.) were also included in the model to provide greater detail on the relationship. The response variable is the presence or absence of Daubenton's passes (sure or unsure) at each survey spot. Surveys with implausibly short (less than 50 minutes) or very long survey times (greater than two hours) were excluded, as these tended to distort the relationship between presence and spot number. F-tests rather than χ^2 tests were used, since they accommodate for the structure of the data better. To complete this task, all of the results from 2011 were included. This dataset is comprised of 398 completed surveys. However, the number of completed surveys used in the analyses for each variable differs depending on the amount of data noted by volunteers (i.e. missing values) (Table 6).

Table 6: Summary of the variables with significant influence on the presence/absences of bat pass at survey spots from binomial GLMM model analysis of the All Ireland Daubenton's Bat Waterway Monitoring Scheme 2011 dataset only

Variable (2006-2010 dataset)	**N completed surveys**	**F-Test**
Minutes after sunset	3980	F=2.45 with 9 and 3449 d.f., P=0.009
Time taken for survey	3980	F=2.12 with 9 and 3434 d.f., P=0.025
Width (m)	3850	F = 3.08 with 4 and 228 d.f., P=0.017
Temperature (°C)	3850	F = 2.18 with 5 and 274 d.f., P=0.056 for quadratic
		F = 7.33 with 1 and 290 d.f., P=0.007 for linear term
Trees at spot level	3850	F = 13.89 with 2 and 3293 d.f., P<0.001
Hedges at spot level	3850	F = 7.18 with 2 and 3491 d.f., P=0.010
Street lights at spot level	3850	F = 5.94 with 1 and 3663 d.f., P=0.015
Rain	3840	F = 3.34 with 2 and 184 d.f., P=0.038

As in previous years of analysis at the broader scale of waterway site, there are significant interactions between spot number and minutes after sunset (F=2.45 with 9 and 3449 d.f., P=0.009) and time taken for survey (F=2.12 with 9 and 3434 d.f., P=0.025). There is a higher number of Daubenton's bat passes recorded at survey spots surveyed at a later time after sunset and for surveys that are completed over a longer duration.

Waterway width values, as estimated by surveyors, were categorised into five groups (from <2m to >20m). The majority of the waterway sites surveyed in 2011 were entered in the 10m-20m category. This parameter was found to be highly significant (F = 3.08 with 4 and 228 d.f., P=0.017) with bats less likely to be present at survey spots in very narrow waterways. A grouped factor was fitted, since this makes presentation easier, but a quadratic relationship on the log-scale also fits well, because the increase tails off at higher widths. This variable has also been reported as significant for each previous year of the monitoring scheme at the broader scale of waterway site.

Air temperature was recorded by volunteers at the start of the survey night. The values recorded were grouped into six categories (e.g. <10 °C) and applied to the survey spot level. Temperature is significant as a linear fit, with bats more likely to be present at higher temperatures (F = 2.18 with 5 and 274 d.f., P=0.056 for quadratic term but F = 7.33 with 1 and 290 d.f., P=0.007 when fitted as linear term). The highest percentage of survey spots with bat passes was recorded for the temperature category 16.1-18 °C (74.3%) with the lowest number of survey spots with bat passes at the >10 °C temperatures (52.7%).

The 'Rain' parameter is comprised of three categories with the majority of surveys completed during dry weather. This relationship is also significant (F = 3.34 with 2 and 184 d.f., P=0.038) suggesting that a higher proportion of survey spots with bat passes were recorded during dry weather compared to drizzle and light rain categories. This has been true also for previous years' analyses at the broader scale level of waterway sites.

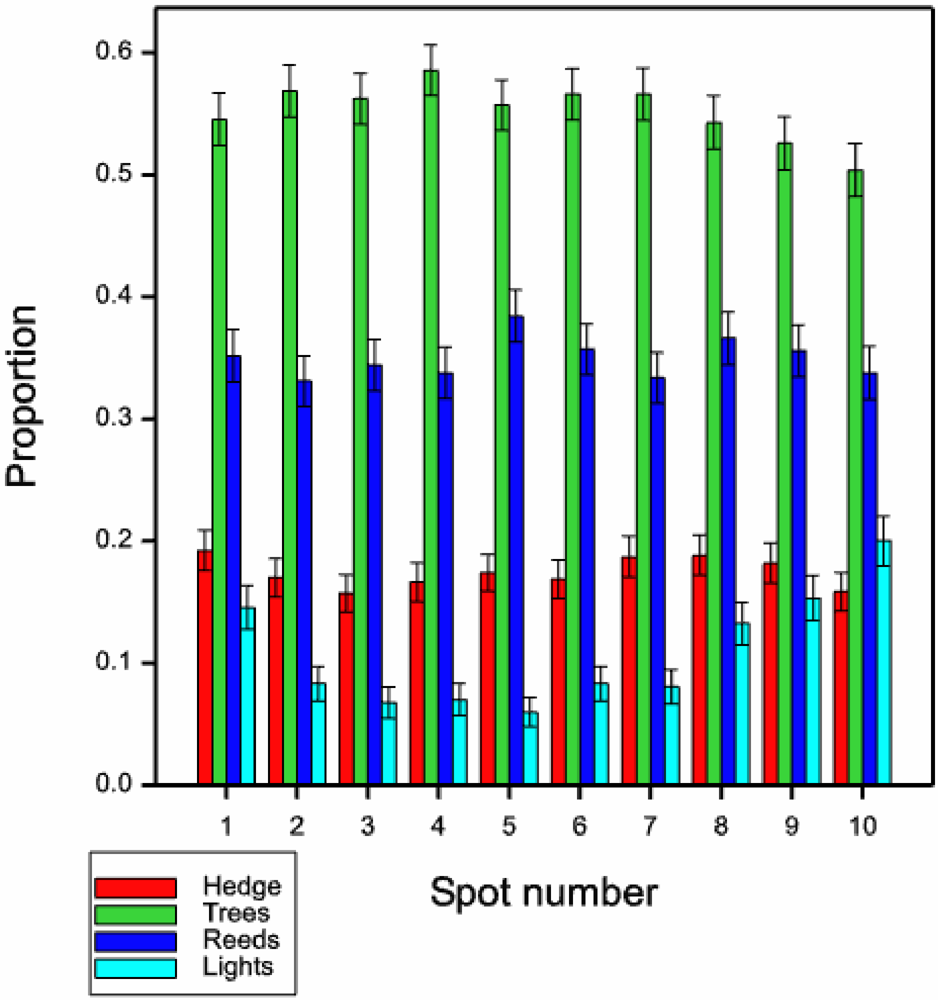
The variables 'sheltered by trees' is the variable that has been collated by surveyors since the inception of the monitoring scheme. It categorises the entire 1km long waterway site into one of three groups: None (no shelter); up to 50% (tree shelter) or greater than 50%. The site level variable for the proportion sheltered by trees was not significant for the 2011 dataset at the survey spot level.

Additional data was collected since 2009 at the survey spot level in relation to the presence or absence of trees, hedgerows or tall vegetation. The presence or absence of trees and hedgerow at survey spots did have a significant influence on the presence of Daubenton's bats while the presence of tall vegetation (e.g. reeds) did not have a significant influence on the number of Daubenton's bat passes at the survey spot level. The presence of trees (F = 13.89 with 2 and 3293 d.f., P<0.001) at the survey spot level had a positive influence on the number of Daubenton's bat passes recorded. The impacts from the effect of trees increases when these are present on both sides, compared to no trees or just trees on one side. The figures in the table (Table 6d, Appendix I) suggest that there is a negative influence on bat activity when hedgerows are present on one or both sides of the waterway site when compared to no hedgerows present at the survey spots. For hedgerows the pattern is rather different in the raw means compared to the back-transformed ones. This may suggest that the presence of hedgerows and their influence on bat activity is a complex relationship that may be dependent on other habitats linked with hedgerows, and or other variables in the model.

Despite the relatively low number of spots with streetlights, this variable is significant at the 5% level with spots with streetlights around 10% less likely to have bat passes (F = 5.94 with 1 and 3663 d.f., P=0.015). The difference is rather larger in the raw percentages (12%), before adjustment for the other variables.

Interestingly, the distribution of trees (F=2.07 with 9 and 1989 d.f., P=0.029) and street lights (F=7.03 with 9 and 1989 d.f., P<0.001) are significantly non-random with respect to spot number. There are, on average, fewer trees in the final few survey spots of each survey site, whilst there are fewer streetlights around spots 3, 4 and 5 of each site. Hedges (F=0.79 with 9 and 1989 d.f., P=0.807) and reeds (F=1.06 with 9 and 1989 d.f., P=0.393) show no significant departures from a random distribution. This is illustrated in Figure 6.

Figure 6: Percentage of survey spots with hedges, trees, reeds or lights. Bars are +/- one standard error.



Finally there is a highly significant, but complex, relationship between spot number and the presence of bats. Looking at the overall means, the main difference is the low proportion for survey spot 1. This has been noted before in both in BCIreland Data and in BCT's NBMP, and presumably indicates that the starting time is slightly earlier than is ideal. However, it is just possible there could be a disturbance effect, if many routes start near main roads, for example. There are significant interactions between spot number and minutes after sunset (F=2.18 with 9 and 3444 d.f., P=0.021) and time taken for survey (F=2.13 with 9 and 3428 d.f., P=0.024 with more Daubenton's bat passes recorded with later starts and longer survey times. The former occurs because, as would be expected, the low proportion at spot 1 also continues to spots 2 and 3 for surveys starting a few minutes early. The latter is more difficult to explain, with the proportion with passes also falling off at the last couple of spots for short survey times.

The potential influence of an additional 15 variables did not yield any significant results. This list is presented as Table 7 in Appendix I.

Water Quality

Testing of the relationships was carried out by adding the water quality variables to the binomial GLMM for the proportion of spots with bats (but with data at the survey level) using only 2006-2011 water quality data. By far the strongest relationship is with biological water quality (Q value), which tallies well with results from Britain. A total of 214 waterway sites with biological data were included in the dataset and the majority of the waterway sites in this dataset had a Q4 value. The linear relationship (using the numerical values in column QValueID of the 'abbreviations' sheet) is highly significant ((F=12.27 with 1 and 165 d.f., P=0.001) and there is a quadratic relationship of borderline significance (F=2.12 with 1 and 142 d.f., P=0.148). The number of waterway sites surveyed under the monitoring scheme with a Q value of 5 is limited to two sites.

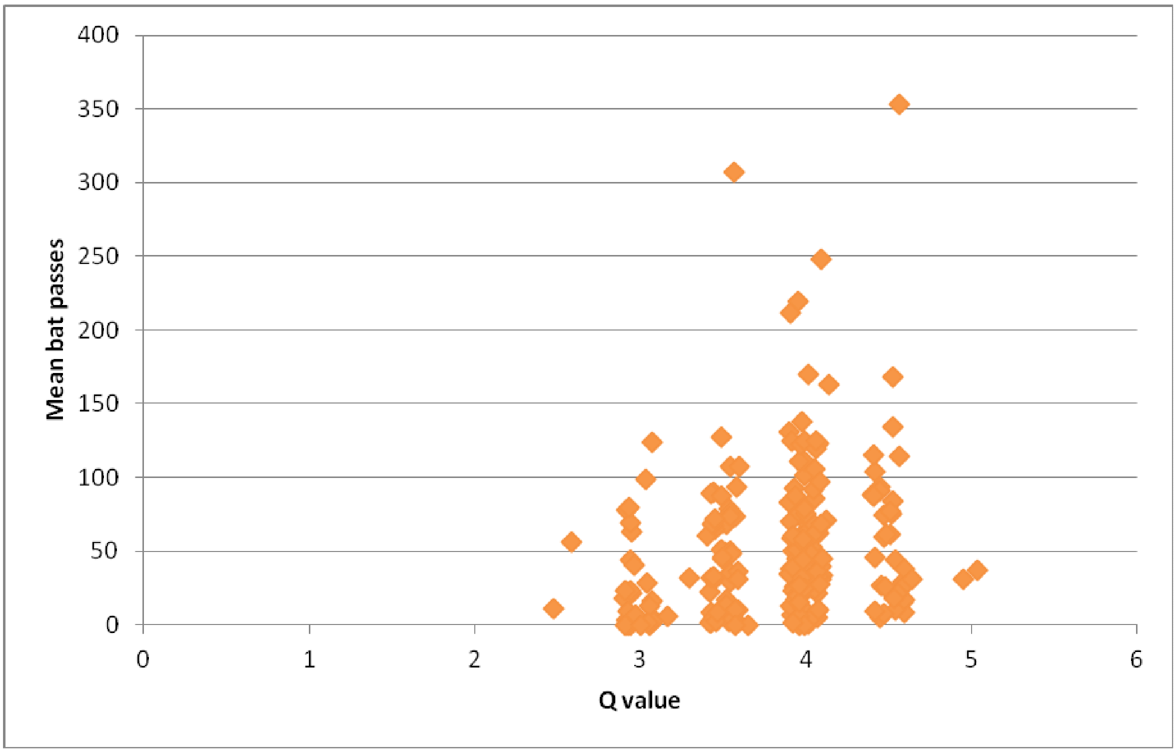


Figure 7: Relationship between mean bat numbers and Q values from 2006-2001 water quality data. Random noise is added to the Q values to avoid coincident points.

Observed and predicted means for the relationship between presence of Daubenton's bats and the Q values are shown in Table 7. The difference is quite striking, with around 20% fewer spots having bats for a Q value of 3 (poor) compared to a waterway with a Q value of 4 (good). It should however be noted that there is some spatial clustering of the Q values, with more good quality rivers in the West, so there is some risk of the effects being confounded with other geographic differences.

Table 7: The effects of biological water quality from the GLMM model. Percentage of spots with bats are shown with standard errors, as well as predicted values on the logit scale, after adjusting for the effects of other factors (river width, spots with smooth water, minutes after sunset, temperature and survey time) in the model.

		Raw data		Adjusted for other variables			
Group	surveys	% with	s.e.	logit	s.e.	back-trans	s.e.
3 poor	115	45.0	1.47	-0.54	0.270	36.8	6.15
3-4 moderate	259	52.2	0.98	0.04	0.206	51.1	5.08
4 good	536	63.5	0.66	0.40	0.197	60.0	4.67
4-5	197	67.7	1.06	0.54	0.250	63.2	5.72

Note: data is only shown for Q value groups with at least 20 sites (i.e. excluding categories such as 3*), but all data is used in fitting the quadratic model.

Table 8 shows test statistics for adding the chemical variables to the GLMM. Chloride is statistically significant with a negative coefficient (i.e. less bats with high chloride). However, chloride is negatively correlated with the Q value and, if both are fitted together, chloride is no longer statistically significant. %OXYGEN (dissolved oxygen % saturation) is also close to significant but, again, is less significant if biological quality is also fitted.

Table 8: Test statistics for adding chemical variables to the binomial GLMM for presence of Daubenton's bats. Terms are added one at a time to a model with covariates for river widths, smooth water, minutes after sunset, temperature and survey time. Biological quality is not included in these models. Includes both Republic of Ireland and Northern Ireland data where data are compatible.

	F	df1	df2	P
ALKALINITY	0.04	1	88	0.843
AMMONIA	0.31	1	88	0.581
BOD	0.17	1	79	0.683
CHLORIDE	6.82	1	93	0.011
CONDUCT	0.50	1	67	0.482
%OXYGEN	3.51	1	93	0.064
NITRITE	0.43	1	92	0.512
PHOSPHATE	0.10	1	77	0.756
PH	0.00	1	87	0.989
TEMPC	0.06	1	90	0.813
HARDNESS	0.00	1	86	0.967
NITROGEN	0.98	1	96	0.324
COLOUR	0.39	1	78	0.533

Yearly Trends

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. This type of analysis was also completed in 2010 and 2011 and 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 six years of data) results suggest a decline to 2008 with numbers rebounding in 2009, 2010 and 2011 (Figure 8) but changes are quite 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.

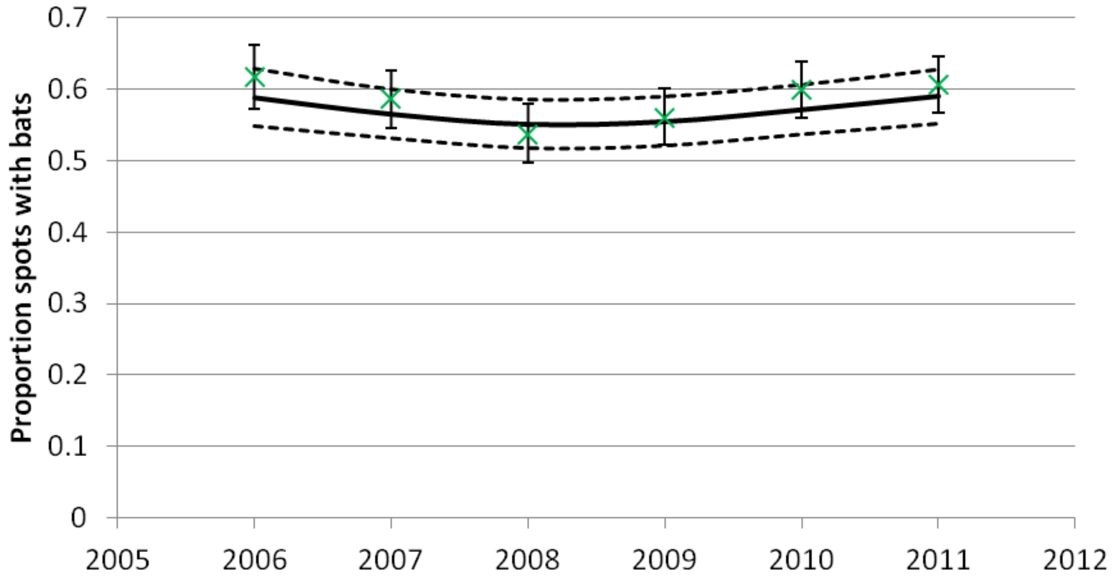


Figure 8: Binomial GAM results without covariates for the All Ireland Daubenton's Bat Waterway Monitoring Scheme 2006-2011. Green points are estimated annual means and the bars are 95% bootstrapped confidence limits. The black line is the fitted GAM curve with 95% confidence limits shown by the dotted lines.

Table 9: 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	223	116	0.597	0.010	0.589	0.020	0.549	0.628	0.617	0.023
2007	324	170	0.568	0.009	0.565	0.017	0.532	0.599	0.586	0.020
2008	293	167	0.534	0.009	0.551	0.017	0.518	0.585	0.537	0.021
2009	332	186	0.561	0.009	0.555	0.017	0.522	0.589	0.560	0.020
2010	370	193	0.619	0.008	0.572	0.017	0.537	0.606	0.600	0.020
2011	312	178	0.617	0.009	0.591	0.019	0.552	0.627	0.606	0.020

Total number of waterway sites used in analysis: 271

b) with covariates for smooth water and temperature

			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	223	116	0.597	0.010	0.601	0.021	0.559	0.640	0.627	0.024
2007	324	170	0.568	0.009	0.585	0.018	0.550	0.620	0.602	0.021
2008	293	167	0.534	0.009	0.577	0.018	0.542	0.612	0.567	0.022
2009	332	186	0.561	0.009	0.584	0.018	0.549	0.620	0.588	0.021
2010	370	193	0.619	0.008	0.602	0.018	0.567	0.639	0.629	0.020
2011	312	178	0.617	0.009	0.622	0.020	0.583	0.661	0.636	0.021

Total number of waterway sites used in analysis: 271

Power Analysis - detecting Amber and Red Alerts for Daubenton's bat

Power Analysis was undertaken in 2009 for the 2006-2008 dataset. This was repeated in 2012 on the entire dataset to ensure that the monitoring scheme is meeting its detection of Amber and Red Alerts in sufficient number of years.

Results of the power analysis are shown in Table 10 in terms of the average numbers of years to detect the specified changes 80% of the time (i.e. with 80% power). They are very similar to the results calculated in 2009, indicating that the extra data collected since then has not had a big impact on the estimates of the variability of the data. Note that these figures are subject to random error because they are based on a limited number of simulations. Despite this, the overall trends are clear, with more years required with less sites. With the results presented, it indicates that between 150 and 200 sites each year should be surveyed to be able to detect Red Alerts in around six years and Amber Alerts in ten years. The figures for a doubling of the population are not dissimilar to those for halving it (i.e. red alert); this is not at all surprising giving the logarithmic nature of the models fitted.

Table 10: Number of years (including the extra years needed at either end of the GAM curve) to achieve 80% power for various scenarios. Whilst the number of years must be an integer in reality results are shown here with one decimal place to aid comparisons. All simulations use two repeat surveys in each year with no missing values.

	Red Alert (50% decline over 25 years)		**Amber Alert (25% decline over 25 years)**		**Increase (doubling over 25 years)**	
Sites	**years**	**s.e**	**years**	**s.e**	**years**	**s.e**
30	8.8	0.3	17.0	1.2	10.2	0.8
40	8.6	0.4	16.3	1.4	9.6	0.8
50	8.0	0.3	14.9	1.2	8.8	0.6
75	7.4	0.4	12.9	0.9	7.5	0.5
100	6.6	0.2	11.1	0.6	7.3	0.7
150	5.6	0.4	9.5	0.5	6.3	0.3
200	5.6	0.4	9.2	0.6	5.6	0.4

Discussion

Volunteers & Survey Coverage

Volunteer uptake

One hundred and ninety one survey teams (minimum two individuals per team), a relatively large number of volunteers, undertook the survey in 2011. As a result of well-attended training courses the number of new volunteer teams participating increased in 2011 to highest number of volunteers participating in any year to date. Over the duration of the six years of the scheme, a total of 467 survey teams have participated in the monitoring scheme. Only 45 survey teams have participated for all six years of the monitoring scheme, but 142 survey teams have continued to participate since joining the monitoring programme. There is a high turnover of volunteers from members of the public and as a consequence 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.

Survey Coverage, Dataset & Distribution in 2006-2011

The highest number of sites was surveyed in 2011 compared with all previous years of the survey. A total of 400 surveys were completed at 225 waterways sites. In total 422 waterway sites have been assessed for Daubenton's bat activity since 2006.

The Daubenton's bat was recorded on the majority of the waterway sites surveyed throughout the duration of the monitoring scheme, 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 in south west Kerry and also at sites on the western seaboard in Mayo. This monitoring scheme is, therefore, making a considerable contribution to our knowledge of the distribution range of the Daubenton's bat. A similarly widespread distribution of this species was reported by the BCT NBMP where Daubenton's bats were recorded from northern Scotland to southern England (www.bats.org.uk).

This large body of information has provided an excellent dataset to investigate the landscape conservation needs of this species (Lundy *et al.*, 2011). This dataset has also provided opportunities to undertake further analysis in relation to factors that potentially influence Daubenton's bat activity levels. It is also a robust dataset to use as a baseline for potentially monitoring the impacts of climate change, urbanisation and habitat degradation.

Statistical Analysis

Variables affecting activity, survey level

Results from binomial analysis for the five years of data suggest that several of the variables tested have a significant impact on the proportion of survey spots with bats. These include the width of waterways surveyed, air temperature recorded by volunteers at the start of the surveys, start time in relation to minutes after sundown, time taken to complete surveys and the duration of the survey, and smoothness of the water surface.

Width of waterway was a highly significant influence on the number of bat passes recorded and under the new model continues to have a significant influence on the number of survey spots with bats. The results suggest that a higher proportion of survey spots with bats are recorded on wider Irish waterways. 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 proportion of survey spots with bats recorded on warmer nights. On nights with a temperature lower than 12° Celsius, a significantly lower proportion of survey spots were recorded with bats. Therefore, we should continue to emphasise the importance of surveying on mild nights to ensure that chances of detecting Daubenton's bats are optimised.

Identification skills of volunteers did not have a significant influence on the proportion of survey spots with bats. However, in general, 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 four years of the survey.

Sunset influences the time at which bats emerge to feed along with 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 survey spots with bats 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 to more than 120 minutes. 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 four 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. There is also the possibility that along transects with no or few bats, surveyors will complete the survey quicker.

The relationships between Daubenton's activity and weather variables recorded by the surveyors or data collated by Met Eireann in the Republic of Ireland were investigated. For rain, there is a clear, negative relationship with a greater proportion of survey spots with bats on dry days. This is not a surprising result. Studies have shown that flight activity of bats is affected by day to day weather conditions with rainfall to reduce bat activity (Erkert 1982). Temperature recorded by the surveyors' assessment is statistically significant while temperature recorded by the met station variables is not significant.

Variables affecting activity – survey spot level

To investigate the potential relationship with variables such as the presence of street lights and riparian vegetation structure (i.e. presence or absence of trees, hedgerows and tall vegetation at each survey spot), the data was fitted to a spot level binomial GLMM model. This was applied to 2011 Daubenton's dataset only.

Vegetation structure and prey availability are known to influence habitat selection by bats (Fenton, 1990). Emerging aquatic invertebrates from the surface of waterbodies provide a plentiful and often predictable supply of prey items for bats (Walsh and Harris, 1996). From the present study, the presence or absence of trees at survey spots was found to have a significant influence on the proportion of survey spots with Daubenton's bat activity, with more bats present at spots with trees on either one side or both sides of the waterway site. The presence of trees may be important for a number of reasons: shelter from weather, protection from predation, providing additional habitats for associated insects and increased shelter may allow aerial swarming insects to gather to the lee of windward. Lundy *et al. (*2011) found that broadleaf woodland was one of the preferred habitat types for Daubenton's bat in Ireland. The presence of adjacent woodlands and improved grassland has been found to exert an influence on bat activity along riparian zones (Lundy and Montgomery, 2009) where feeding rate of bats was positively related to hedgerow length, low intensity agriculture and riparian diversity, but negatively related to high intensity agriculture. In this study, we found that, while Daubenton's were more likely to be present at spots where there are trees on one or both sides, they were less likely to be present if hedgerows were present on the waterway. This result was unexpected and we hypothesise, that the relationship with hedgerows is also affected by adjacent habitats (e.g. intensive agriculture) and or other variables in the model. Therefore, more detail is needed on adjacent habitats to determine relationships with hedgerows and Daubenton's bat activity.

Another aspect of the riparian zone that needs further investigation is the presence or absence of riffles and smooth water at each of the survey spots. Daubenton's bat feeds by trawling insects from the smooth surface of waterbodies (Norberg and Rayner, 1987) and has been reported to avoid turbulent riffle zones (Rydell *et al.*, 1999). These two contrasting riparian features often reflect the size of the waterbody. Wider lowland rivers often have less riffle zones in comparison to narrow more upland rivers. Lundy *et al.* (2011) predicted that the Irish core range of the species was the central regions of the island. This region tends to have a higher proportion of the slow moving rivers and abundance of lakes that this species favours for foraging.

Riparian zones are essentially linear landscape features and are necessary for commuting and foraging bats. They often provide abundant prey items, shelter from inclement weather, acoustic orientation and protection from predators. However, reliance on such linear features makes bats vulnerable to habitat fragmentation. Street lights may fragment these habitats causing bats to alter their commuting and foraging behavior (e.g. see Stone *et al.* 2009). As urbanisation expands into the landscape, the degree of street lighting also extends. Despite the relatively low number of survey spots with street lights in the 2011 dataset, this variable has a significant impact as survey spots with street lights are around 10% less likely to have bat passes. While a more detailed examination of the location of such waterway sites in the landscape is required, this preliminary work is of interest. It also contrasts with BCIreland's findings regarding Leisler's bat activity along roadsides which was confirmed to increase with the occurrence of yellow and white street lights (Roche *et al.*, 2012). Such differences may be expected; Rydell (1992) predicted that slow flying, short range echolocating bats are likely to avoid street lighting while fast flying long-range echolocators (such as Leisler's bats) are likely to exploit the increased abundance of insects at street lights. As this monitoring scheme measures the activity levels of Daubenton's bats on rivers and canals, it is an ideal opportunity to investigate the potential impacts of street lighting along these sites and devise management guidelines for rivers and canals in urban areas.

Street lights are more common at either end of a waterway site route, but particularly the far end (high spot numbers), whereas the reverse is true for trees. Presumably this is because people tend to start or finish their routes near main roads. Survey teams are also advised to start at the furthest point away from their parked car which can often be at a car park of a local landmark or the grid referenced bridge. Therefore, the first survey spot tends to be located further away from potentially lit areas. This is a very interesting example of how a survey of this type can produce subtle biases in the habitat examined compared to a completely random allocation of spots – the latter would, of course, be very difficult to do in practice, but is theoretically what a good design should achieve.

Water Quality

Macroinvertebrate monitoring of rivers is an important element in assessing the ecological status of rivers in Ireland. This ecological status is quoted as a Q-value index in the Republic of Ireland and consists of 12 Q-value categories and four status categories. Daubenton's bat activity shows a strong relationship with biological water quality (Q value), which tallies well with results from Britain (Catto *et al*., 2003 and Langton *et al.,* 2010). While the number of waterway sites with a Q5 value was too low to make any statistical conclusions, there was high proportion of waterway sites with a Q4 and Q4.5 values. In relation to Q value of 4 and Q value of 4.5, these waterway sites have all 'Indicator Groups' of macroinvertebrates present which means that the macroinvertebrate community is diverse. The difference is quite striking, with around 20% fewer spots having bats for a Q value of 3 (poor) compared to a waterway with a Q value of 4 (good). A Q value of 3 means that the most sensitive 'Indicator Group' (e.g. stoneflies except *Leuctra* spp. and mayflies) is absent and a few specimens from Group B (e.g. mix of particular genera of mayflies, cased caddis flies etc) may be present. However, the macroinvertebrate community is much reduced in comparison to a Q value of 4. Cased caddis flies are represented in Group B and Abbot *et al.* (2009) reported that Daubenton's bat activity was highest up-stream of sewage treatment plants. She attributed this level of bat activity to the significantly higher abundance of cased caddies flies which is considered as an important as a source of food for this bat species in Ireland where Sullivan *et al. (*1996) and Flavin *et al.* (2001) reported that Trichoptera accounted for 30% and 26% respectively of the diet

There is some spatial clustering of the Q values, with more good quality rivers in the West, so there is some risk of the effects being confounded with other geographic differences. This would merit further investigation. We propose to introduce some stratified sampling to our survey to ensure that there are a minimum number of waterway sites of each Q value sampled in each province with special emphasis on Q value categories which are under-represented in the current dataset e.g. Q value of 5.

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 August 2007 and 2008 may have been a factor influencing this decline. Poor weather conditions also occurred in August 2009 but Daubenton's bat activity showed a slight recovery. This recovery continued in 2010 and 2011 which, overall, had better weather conditions during the survey period compared to previous years. However, additional years of data are required before making any conclusions about trends. No significant trend has been noted for the Daubenton's bat in Britain (Anon, 2010). In 2009 for the first time, we examined trends using a binomial method. This is considered 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 less likely to have an impact on overall trends (MacKenzie *et al*, 2006). As a result, the binomial model was again used in 2011. 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 from the same individuals. We propose to continue to use this binomial method as the main tool for tracking Daubenton's bat trends as the monitoring scheme progresses.

Power Analysis

Power analysis shows that if 150 to 200 waterway sites are surveyed each year, it should be possible to detect Red Alerts in around six years and Amber Alerts in ten years. These results are very similar to those reported in Aughney *et al.* (2009). The overall trends show that more years are needed to detect declines when fewer sites are surveyed. However, if more than 100 sites are surveyed annually there is little power gained. Instead, there is an advantage with more sites in that it improves the power of regional estimates (maybe at province level, or a contrast between the west and the east, for example). There is also the possibility of providing estimates for the Republic of Ireland and Northern Ireland separately which may benefit reporting requirements for the two separate countries.

Future Investigations into Climate Change

As global climate change is an important element that may impact on the distributions of bats globally, it is important to seek means of ensuring that data from monitoring schemes aim to address this area. Rebelo *et al.* (2009) predicted a decrease in the Daubenton's bat European range by the middle of the present century as a result of global climate change. Our dataset provides detailed information on the distribution of Daubenton's bat across the island and we are well-placed to further investigate the potential impacts of island-wide and regional climate change scenarios on Daubenton's bats range and population.

Conclusions

- The All Ireland Daubenton's Bat Monitoring Scheme is a suitable monitoring scheme for volunteer participation. The training courses and support allow volunteers to collect robust data on the activity levels of Daubenton's bats on waterways. However annual recruitment is required to ensure that a sufficient number of waterway sites are surveyed to meet Red and Amber Alert Levels.
- Yearly trend analysis, completed by Binomial GLM/GAM model, results suggests that there was a decline to 2008 with numbers rebounding in 2009, 2010 and 2011.
- Power analysis determined that the number of waterway sites sufficient to monitor Red (within 6 years) and Amber Alert (within 10 years) targets, in a reasonable time frame, are between 150 and 200 waterway sites surveyed annually.
- Binomial GLMM/GAM model proved to provide more suitable for analysis on the impact of the various covariates on the probability of observing bats at a survey spot compared to REML model. Daubenton's are more likely to be present on waterway corridors of 10-20m wide.
- The presence of street lights causes a reduction in Daubenton's bat activity by 10-12%.
- Water quality is an important influence on Daubenton's bat activity and analysis has shown that a Q value is 3 (poor) results in around 20% fewer survey spots with Daubenton's bats compared to spots with a Q value of 4 (good).
- The temperature data recorded by surveyors correlates better with Daubenton's bat activity than the temperature data from met stations while Met Eireann rain data proved to correlate batter with Daubenton's bat activity than rain data collected by surveyors.

Recommendations

Recommendation 1	Continue to survey Daubenton's bats using the current methodology. In particular, sites should continue to be surveyed twice in the month of August and start time should remain at 40 minutes after sunset.
Recommendation 2	Aim to survey a minimum of 150 sites twice annually.
Recommendation 3	To increase the robustness of the data, waterway sites surveyed in previous years should be prioritized for re-survey; sites surveyed in all 6 years to date should given top priority, followed by sites surveyed in 5 of the last 6 years etc.
Recommendation 4	Strive to survey a minimum of 5 waterway sites per county with an aim of 50 waterway sites per province to allow for regional difference to be investigated. New waterway sites should be selected from water quality datasets currently monitored by the EPA (Republic of Ireland) and NIEA (Northern Ireland). Consider stratifying the sampling to ensure that sites of varying water quality are covered.
Recommendation 5	Continue to provide annual training courses as a means to recruit new volunteers and as a means to provide education on the conservation of bats in general. Where necessary to ensure continuity of waterway sites, new volunteers should be deployed to cover waterway sites previously surveyed. Otherwise, continue to provide volunteers with three potential ten-figure 'Grid Referenced Water Quality Sampling Sites' within 10km radius of their preferred survey area.
Recommendation 6	Improve technical support for volunteers by providing an Android Training App. which should be made available on the App. market prior to the next survey season. In addition, provide an online survey form to allow non-Android telephone users to enter data remotely and send by email. Continue to provide volunteer support by email, Daubenton's Bat newsletters and training programmes.
Recommendation 7	Continue to utilise regional paid-surveyors to ensure that core sites are surveyed twice annually.

Recommendation 8	Continue to employ a professional statistician with experience of bat data interpretation to carry out analysis of the data. Future statistical analysis should concentrate on binomial analysis of collated data for assessing population trends, but models based on counts of bats should continue to be checked for any differences from the binomial model. Trend analysis should be undertaken annually, and the effectiveness of the design reviewed once every 3 years, for example by undertaking power analysis and by checking the coverage of sites and continuity of recording at sites.
Recommendation 9	Continue to collate additional information on the waterway sites at survey spot level. Liaise with universities to set up projects to investigate further the potential influence of lighting and riparian vegetation structure of selected waterway sites.
Recommendation 10	Investigate further habitat analysis using GIS. Detailed habitat analysis will provide valuable information for conservation of Daubenton's bats.
Recommendation 11	Max Ent modeling at island-wide, and if possible, regional scale using EPA/Met Eireann climate change scenarios, to assess potential impact of climate change on Daubenton's bat.
Recommendation 12	Undertaken the monitoring scheme on an all-island basis with continued cooperation between agencies in Northern Ireland and the Republic of Ireland. Encourage and sustain the involvement of NPWS and NIEA Regional Staff, Local Authorities' Heritage and Biodiversity Officers and Waterways Ireland in the organization of training courses and the surveying of waterway sites. Seek further partnership with Environmental Protection Agency, Republic of Ireland and Water Quality Unit, NIEA.

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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.

GLM

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

GAM

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

Offset

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

Poisson Distribution

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

Power Analysis

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

REML

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

Relative Standard Error

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

Appendices

Appendix 1

The following tables present the data used in statistical analysis. Survey completed after the first week of September in each year has been excluded for analysis.

Summary Statistics

Table1: Basic statistics of completed surveys used in statistical analysis in 2006-2011

Connaught

Year	n completed surveys	mean sure bat passes	mean unsure bat passes	all bat passes	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	59	55.7	10.5	66.2	62.2	96.6	56.4
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
2010	55	68.9	5.8	74.7	71.7	92.7	63.8
2011	59	58.8	5.4	64.3	61.6	89.8	60.5
All years	323	61.4	9.6	71.0	65.8	92.3	58.8

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	194	37.5	6.7	44.2	43.4	89.7	55.5
2008	135	33.4	5.6	39.0	38.0	85.9	52.9
2009	169	37.4	7.7	45.1	44.1	90.3	54.8
2010	178	49.4	10.0	59.3	55.7	95.5	63.5
2011	162	46.5	7.6	54.1	53.2	94.4	62.3

All years	940	41.4	9.8	51.2	47.7	91.7	58.3

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	78	42.3	6.5	48.8	43.8	89.2	45.8
2010	76	48.1	12.3	60.4	58.7	94.7	59.6
2011	83	57.1	17.3	74.4	67.6	97.6	63.1
All years	449	47.4	10.9	58.2	54.2	93.0	55.1

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	49	29.9	8.7	38.6	37.7	95.9	56.9
2008	61	39.8	9.9	49.7	48.7	96.7	56.9
2009	80	46.0	9.6	55.6	53.1	95.0	60.2
2010	93	48.8	7.5	56.3	53.0	90.3	58.2
2011	94	55.2	9.6	64.9	60.7	92.6	63.6
All years	412	44.7	9.7	54.4	51.9	93.2	59.1

All Sites

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	382	41.6	7.7	49.3	47.4	91.6	54.8
2008	311	37.7	7.0	44.7	42.5	90.7	53.1

2009	379	45.4	8.0	53.4	50.4	90.6	55.2
2010	402	51.7	9.3	60.9	57.8	93.8	61.6
2011	398	52.6	9.8	62.4	59.2	94.0	62.5
All years	2124	46.4	10.0	56.3	52.7	92.3	57.9

With very skewed data, means can be misleading as they are easily distorted by a few very large values. Therefore the percentiles are shown in Table 2 (e.g. if the data are arranged in ascending order, the 25th percentile is the value 25% along the line).

Table 2: Basic statistics: percentiles of the distribution of total counts (Daubenton's and Unsure bat passes) in 2006-2011

Percentile	minimum	5th	10th	25th	50th/median	75th	90th	95th	maximum
2006	0	0	2	7	34	80	138	202	1568
2007	0	0	1	9	30	68	112	165	377
2008	0	0	1	9	30	61	105	139	391
2009	0	0	1	9	36	72	123	191	356
2010	0	0	3	12	40	83	139	189	606
2011	0	0	2	13	42	91	154	199	406

Table 3: Basic statistics: number of years data from each site (excludes survey outside the set survey date range)

Number of years	Number of observers	% of total	Cumulative %
1	149	35.5	35.5
2	74	17.6	53.1
3	58	13.8	66.9
4	52	12.4	79.3
5	42	10.0	89.3
6	45	10.7	100.0

Table 4: Basic statistics: matrix of waterway sites surveyed in all possible pairs of years and used in statistical analysis (e.g. 118 waterway sites were surveyed in 2007 and 2008). Number on the diagonal (italics) are total waterway sites surveyed in each year.

2006	*132*					
2007	100	*201*				
2008	87	120	*180*			
2009	79	120	137	*211*		
2010	77	113	116	142	*211*	
2011	69	104	107	130	154	*224*
	2006	**2007**	**2008**	**2009**	**2010**	**2011**

* Note: Number of waterway sites used in statistical analysis may differ to the number of submitted waterway sites submitted to BCIreland e.g. in 2006, 134 survey forms received, 132 used in analysis.

GLMM Model 2006-2010 Analysis

Table 5: Effects of factors from the GLMM model (2006-2010 data). Percentage of spots with bats are shown with standard errors, as well as predicted values on the logit scale, after adjusting for the effects of other factors in the model. The number of surveys is for the raw means; adjusted means are based on fewer surveys due to missing values amongst the covariates. The absolute value of the adjusted means is not informative due to the averaging over other terms, but the relative sizes indicate where the differences lie; standard errors are applicable to the logit values, but back-transformed values are easier to interpret.

(a) Width (F = 10.67 with 1 and 529 d.f., P=0.001 for quadratic term)

	Raw data			Adjusted for other variables		
Group	surveys	% with	s.e.	logit	s.e.	back-trans
2m or less	7	31.4	5.55	0.81	1.235	69.3
<=5m	379	46.5	0.81	0.15	0.170	53.9
<=10m	609	59.2	0.63	0.53	0.155	62.8
<=20m	268	63.3	0.93	0.57	0.183	63.9
>20m	202	70.6	1.01	0.84	0.225	70.0

(b) Smooth/calm water (F = 6.06 with 3 and 435 d.f., P<0.001)

	Raw data			Adjusted for other variables		
Group	surveys	% with	s.e.	logit	s.e.	back-trans
None	62	38.5	1.97	-0.46	0.273	38.6
up to 50%	407	50.5	0.78	0.20	0.174	55.1
greater that 50%	992	62.6	0.49	0.53	0.155	62.8
Not noted	5	60.0	6.93	1.10	0.994	75.1

(c) Minutes after sunset (F = 9.49 with 1 and 950 d.f., P=0.002, fitted as linear term)

	Raw data			Adjusted for other variables		
before 30 mins	76	60.8	1.78	0.59	0.207	64.3
30-40mins	384	56.2	0.80	0.61	0.162	64.7
40-50mins	604	57.0	0.64	0.53	0.155	62.8
50-70mins	201	60.3	1.09	0.78	0.170	68.6
70-90mins	56	69.9	1.93	0.84	0.224	69.8
before 30 mins	76	60.8	1.78	0.59	0.207	64.3

(d) time taken for survey (F = 7.55 with 2 and 1041 d.f., P=0.006)

	Raw data			Adjusted for other variables		
Group	surveys	% with	s.e.	logit	s.e.	back-trans
<=60min	219	52.4	1.07	0.29	0.175	57.1
61-75min	478	58.6	0.71	0.53	0.155	62.8
76-90min	385	59.4	0.79	0.58	0.157	64.2
over 90min	213	64.2	1.04	0.70	0.169	66.7

(e) temperature recorded by surveyor (F = 6.88 with 1 and 907 d.f., P=0.009)

	Raw data			Adjusted for other variables		
Group	surveys	% with	s.e.	logit	s.e.	back-trans
<=10C	103	58.7	1.54	0.27	0.188	56.8
10.1-12C	242	53.9	1.01	0.40	0.162	59.8
12.1-14	396	58.0	0.78	0.53	0.155	62.8
14.1-16	384	58.1	0.80	0.41	0.156	60.1
16.1-18	190	60.1	1.13	0.58	0.172	64.2
over 18C	53	60.9	2.12	0.72	0.218	67.3

(f) rain in 24 period derived from met data (F = 10.55 with 1 and 674 d.f., P=0.001)

	Raw data			Adjusted for other variables		
Group	surveys	% with	s.e.	logit	s.e.	back-trans
no data*	82	62.3	1.69	0.72	0.314	67.2
<0.5mm	441	60.5	0.74	0.58	0.156	64.0
<2mm	488	57.7	0.71	0.53	0.155	62.8
<5mm	245	57.8	1.00	0.50	0.160	62.2
5mm+	212	53.0	1.09	0.27	0.166	56.7

*'No data' refers to sites more than 50km from the nearest met station with readings on the survey date.

GLMM Statistics 2011 dataset

Table 6: Effects of factors from the GLMM model. Percentage of spots with bats are shown with standard errors, as well as predicted values on the logit scale, after adjusting for the effects of other factors in the model. The number of surveys is for the raw means; adjusted means are based on fewer surveys due to missing values amongst the covariates. The absolute value of the adjusted means is not informative due to the averaging over other terms, but the relative sizes indicate where the differences lie; standard errors are applicable to the logit values, but back-transformed percentages are easier to interpret.

(a) Width (F = 3.08 with 4 and 288 d.f., P=0.017)

	Raw Data			Adjusted for other variables		
Group	spots	% with	s.e.	logit	s.e.	back-trans
2m or less	80	13.8	3.85	-1.88	0.776	13.3
<=5m	1020	55.2	1.56	-0.50	0.333	37.8
<=10m	1570	65.3	1.20	0.13	0.299	53.3
<=20m	630	66.0	1.88	0.14	0.372	53.4
>20m	550	70.2	1.94	0.33	0.400	58.2

(b) Temperature at start of survey (F = 2.18 with 5 and 274 d.f., P=0.056 but F = 7.33 with 1 and 290 d.f., P=0.009 when fitted as linear term)

	Raw Data			Adjusted for other variables		
Group	spots	% with	s.e.	logit	s.e.	back-trans
<=10C	400	52.7	2.50	-0.73	0.332	32.5
10.1-12C	1240	62.2	1.37	-0.26	0.260	43.6
12.1-14	1270	62.4	1.36	-0.12	0.265	46.9
14.1-16	690	64.5	1.82	0.12	0.284	52.9
16.1-18	230	74.3	2.87	0.17	0.378	54.2
over 18C	20	60.0	10.93	-1.30	1.103	21.4

(c) Tree at spot level (F = 13.89 with 2 and 3293 d.f., P=0.001)

	Raw Data			Adjusted for other variables		
Group	spots	% with	s.e.	logit	s.e.	back-trans
None	1159	52.7	1.47	-0.81	0.315	30.8
One side	1128	63.0	1.43	-0.19	0.310	45.3
Both sides	1563	69.1	1.17	-0.07	0.310	48.3

(d) Hedgerows at spot level (F = 7.18 with 2 and 3491 d.f., P=0.010)

	Raw Data			Adjusted for other variables		
Group	spots	% with	s.e.	logit	s.e.	back-trans
None	2821	63.8	0.90	-0.05	0.297	48.8
One side	715	56.9	1.85	-0.52	0.314	37.3
Both sides	314	62.1	2.73	-0.50	0.344	37.7

(e) Street lights at spot level (F = 5.94 with 1 and 3663 d.f., P=0.0315)

	Raw data			Adjusted for other variables		
Group	surveys	% with	s.e.	logit	s.e.	back-trans
absent	3436	64.0	0.82	-0.18	0.297	45.5
present	414	49.0	2.46	-0.53	0.324	37.0

(f) Rain (F = 3.12 with 2 and 188 d.f., P=0.0046)

	Raw data			Adjusted for other variables		
Group	surveys	% with	s.e.	logit	s.e.	back-trans
dry	3390	63.2	0.83	0.04	0.273	51.1
drizzle	360	58.9	2.59	-0.54	0.342	36.7
light rain	90	46.7	5.26	-0.34	0.467	41.5

(g) Spot (F = 4.922 with 9 and 3449 d.f., P<0.001)

	Raw data			Adjusted for other variables		
Group	surveys	% with	s.e.	logit	s.e.	back-trans
1	385	53.2	2.54	-0.85	0.324	29.9
2	385	63.4	2.45	-0.23	0.326	44.3
3	385	63.9	2.44	-0.20	0.327	45.0
4	385	66.0	2.41	-0.07	0.326	48.3
5	385	67.8	2.37	0.05	0.327	51.2
6	385	62.9	2.46	-0.25	0.325	43.8
7	385	64.7	2.43	-0.16	0.326	46.1
8	385	62.1	2.47	-0.29	0.324	42.7
9	385	62.9	2.46	-0.23	0.324	44.3
10	385	57.1	2.52	-0.58	0.322	35.8

Table 7: Test statistics for variables not included in the final model.

term	F	df1	df2	P
EAST	0.00	1	197	0.967
NORTH	0.07	1	199	0.790
PERIOD	1.18	1	179	0.280
DAYNO	0.09	1	199	0.760
CLOUD	1.60	2	215	0.205
WIND	1.09	2	185	0.338
START	0.07	1	200	0.789
END	0.91	1	250	0.342
SMOOTHWATER	0.90	2	271	0.406
CLEAR	0.28	1	253	0.599
Hedge	0.04	1	1024	0.851
Trees	2.45	1	519	0.118
Reeds	0.03	1	585	0.854
EXPERIENCE	0.08	3	191	0.973
IDSKILLS	0.72	3	199	0.543
DETECTOR	1.08	13	189	0.377

Appendix II

Waterway sites surveyed under the All-Ireland Daubenton's Bat Waterway Monitoring Scheme 2006-2011. County by county listing of waterways surveyed by the All-Ireland Daubenton's Bat Waterway Survey 2006-2011.

(Shading = completed survey (does not state if 1 or 2 surveys was completed annually); D = Daubenton's bat passes recorded)

Leinster, County Meath

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1001	River Boyne	Slane Bridge	N9640073610	D	D	D	D	D	D
1002	River Blackwater	O'Dalys Bridge	N6530080320	D	D	D	D	D	D
1003	Borora River	Moynalty Bridge	N7352082560	D	D	D	D	D	D
1029	River Boyne	Ramparts	N8740067400	D	D	D	D	D	D
1030	Blackwater River	Donaghpatrick Bridge	N8194072310	D	D		D	D	D
1031	Athboy River	Athboy Bridge	N7169064260	D	D	D			D
1038	Tolka River	Dunboyne-Loughsallagh Br	O0280041700						
1068	River Nanny	Dardistown Bridge	O1114070200	D	D	D	D	D	D
1132	River Blackwater	Mabe's Bridge	N7361077290	D		D	D	D	D
1204	River Boyne	2km d/s Blackwater confl.	N8852069110		D				
1221	Boyne	Kilnagross Bridge	N7710056800				D		
1251	Broadmeadow	Milltown Bridge	O0721051770						
1283	River Boyne	Trim Walkway	N8069056480			D			
1284	River Boyne	Trim Castle	N8019056889			D	D	D	D
1293	Royal Canal	Sli na Canala, Enfield	N7750041300						
1295	Upper Inny River	Jobson's Bridge	N5295480707					D	
1296	Upper Inny River	Ross Bridge	N4729183034					D	D
1300	River Boyne	Derryingdaly Bridge	N7660053950				D	D	D
1308	River Boyne	Ballyboggan Bridge	N6385040300				D		
1310	River Boyne	Broadboyne Bridge	N9160071200					D	
1315	Broadmeadow	Ashbourne	O0639752231						

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1353	River Boyne	Bellewstown	N7620055800					D	D
1371	River Nanny	Bellewstown Bridge	O0731769153					D	
1375	River Boyne	Scurlockstown Bridge	N8158956837					D	
1414	River Boyne	Scariff Bridge	N7340052600						D

Leinster, County Dublin

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1004	Ward River	Bridge nth of Killeek	O1453046397				D		
1035	Delvin River	Gormanstown Bridge	O1707665774				D	D	D
1037	Tolka River	Cardiff Bridge	O1260037700	D					
1039	Tolka River	Abbotstown Bridge	O0930038300	D					
1040	River Dodder	Oldbawn Bridge	O0975026300	D	D		D		D
1041	River Dodder	Bridge on Spring Avenue	O1361028910	D	D	D	D	D	D
1046	Royal Canal	Collins Bridge	O0280036750	D		D		D	D
1047	Royal Canal	Granard Bridge, Castleknock	O0940038100		D		D	D	D
1048	Grand Canal	Kilmainham Section	O1280033200	D	D		D	D	D
1094	River Dodder	Newbridge Firhouse	O1145027750		D		D	D	D
1131	River Dodder	Milltown Bridge	O1698030410	D			D		
1177	Grand Canal	Hazelhatch Bridge	N9880030700	D		D			
1193	Boradmeadow	Swords Golf Course	O1488150004						
1217	River Dodder	Castlekelly Bridge	O1110020260		D		D	D	
1219	Rye Water	Rye Bridge	O0040035800				D		D
1249	Tolka River	Violet Hill Drive, Finglas	O1430037400				D		
1271	River Dodder	Clonskeagh Bridge	O1750030700		D	D		D	
1301	River Liffey	War Memorial Gardens	O1170034150				D		
1343	Royal Canal	Ashtown Station	O1105037450				D		
1004	Ward River	Bridge nth of Killeek	O1453046397				D		
1035	Delvin River	Gormanstown Bridge	O1707665774				D	D	D
1037	Tolka River	Cardiff Bridge	O1260037700	D					

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1039	Tolka River	Abbotstown Bridge	O0930038300	D					

Leinster, County Wicklow

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1005	Vartry River	Newrath Bridge	T2860096800	D	D	D	D	D	D
1006	Kings River	Ballinagree Bridge	O0364002380						
1007	Avonmore River	Ballard Bridge	T1442095670	D	D	D	D	D	D
1008	Glencullen River	Glencullen Bridge	O2190017900	D					
1009	Vartry River	Nun's Cross	T2560097900	D	D				
1010	River Ow	Roddenagh Bridge	T1170079200	D	D		D	D	D
1012	Dargle River	Bray Bridge	O2640118895	D		D	D		
1013	River Slaney	Seskin Bridge	S9770093900	D		D	D	D	
1083	Avonmore River	Clara Bridge	T1690092100		D	D		D	D
1090	Derry River	Tomnafinoge Wood	T0190070300		D	D	D	D	D
1213	River Dereen	Ballykilduff Townland	S9000070900			D			
1227	River Dargle	Ballinagee Bridge	O2040014700		D			D	
1252	River Dargle	Tinehinch Bridge	O2212516160		D	D	D		D
1255	Varty River	Ashford Bridge	T2704797405		D	D		D	D
1274	Glencullen River	Knocksink Bridge	O2190017900		D		D		
1275	Avonmore River	Clara Vale	T1845591104		D	D	D	D	D
1285	Glencullen River	Glencullen/Dargle confluence	O2430017200		D				
1286	Vartry River	Annagolan Bridge	T2220099300		D	D	D		
1311	Altidore River	Mountkennedy Wood	O2630906937					D	
1348	Glencree River	Wooden Bridge	O1920014700				D	D	D
1365	Glencullen River	Knocksink Nature Reserve	O2000018000				D		
1374	Vartry River	Devil's Glen	T2310098900					D	D

Leinster, County Longford

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1011	Camlin River	The Mall Bridge	N0610075700		D	D	D	D	D
1023	Royal Canal	Aghnaskea Bridge	N0860080500						
1024	Inny River	Newcastle Bridge	N1830057000		D	D	D	D	D
1034	Inny River	Ballymanhon Bridge	N1520056500		D	D	D	D	D
1044	Royal Canal	Farranyoogan	N1300074200		D				
1045	River Rinn	Cloonart Bridge	N0830083200		D				
1100	Inny River	Shrule Bridge	N1350055900		D	D	D	D	D
1299	Camlin River	Carrigglass Bridge	N1650078000						
1338	Royal Canal	46th Lock	N0630075350				D		
1341	Royal Canal	Scally's Bridge	N2300060100		D		D		D
1379	Royal Canal	Atchies Bridge	N1370058000						D

Leinster, County Westmeath

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1032	Brosna River	Ballinagore Bridge	N3560039600	D				D	D
1086	Royal Canal	Bellmount Bridge	N3950051100		D	D	D	D	D
1088	River Brosna	Newell's Bridge	N3830042300		D	D	D	D	D
1093	Tributray of Boyne	Ballivor Road Bridge	N6030345270		D				
1140	River Shannon	Burgess Park, Athlone	N0410041000	D					
1173	Boor River	Kilbillaghan Townland	N1180034950						
1201	Lacey's Canal	Butler's Bridge	N4200050300			D	D		
1209	Brosna River	Mill Race Coola Mills	N4200050200		D				
1232	Inny River	Coolnagon Bridge	N3872470037		D				
1234	Breensford River	Unknown	N1040044400						

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1236	Inny River	Ballycorkey Bridge	N3120063900		D	D		D	D
1257	Royal Canal	Ballinea Bridge	N3850051100		D	D	D	D	D
1306	Royal Canal	D'Arcy's Bridge	N5920049800				D		

Leinster, County Kildare

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1036	River Liffey	Leixlip Bridge	O00075035810	D	D			D	
1042	Grand Canal	Henry Bridge	N9560028200	D	D		D	D	D
1116	Grand Canal	Spencer Bridge	N6680018900			D	D	D	D
1125	Grand Canal	Corbally Line/Limerick Bridge	N8730018700						
1126	River Liffey	Kilcullen Bridge	N8424009730	D	D	D		D	
1127	River Liffey	Connell Ford	N8135013680	D	D				
1128	Royal Canal	Deey Bridge	N9790037000	D	D	D			
1130	Royal Canal	Smullen Bridge	N9410037400						
1142	Grand Canal	Milltown Bridge	S6550097500	D					
1143	Grand Canal	Ayimer Bridge	N9730029500	D	D	D	D	D	D
1165	River Liffey	Ballymore Eustace Bridge	N9262009790	D				D	
1203	Royal Canal	County Meath Bridge	N8860039600			D	D	D	D
1240	Royal Canal	Chambers Bridge	N9000038800			D			
1250	Grand Canal	Ponsonby Bridge	N9370026600		D				
1256	River Liffey	New Bridge	N8704009850		D				
1314	Grand Canal	Pike Bridge, Carton Gate	N9612637359					D	D
1344	Royal Canal	Louisa Bridge	N9945036650						
1380	Slate River	Bridge Street, Rathangan	N6725919354						D
1381	River Liffey	Liffey Park, Clane	N8800027100						D
1395	Royal Canal	Jackson's Bridge	N9180037600						D
1413	Rye River	Carton Estate	N9590038100						D
1419	Grand Canal	Pluckerstown	N7470021000						D

Leinster, County Louth

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1067	River Fane	Stephenstown Bridge	J0139001610		D	D	D		
1211	Castletown River	Toberona/St John's Bridge	J0300009700		D			D	
1212	Kilcurry River	Bridge near Lurgankeel	J0272811980		D			D	
1214	River Dee	Bridge in Ardee	N9528590665						
1215	Dee River	Drumcar Bridge	O0660091170		D				
1220	Boyne Canal	Oldbridge	O0460076200		D			D	D
1222	River Glyde	Castlebellingham	O0600095100		D				
1225	River Boyne	Beaulieu Bridge	O1250075900					D	D
1356	River Boyne	Obelisk Bridge	O0455076250				D	D	D
1357	River Boyne	New Bridge, Drogheda	O0842675139				D	D	D
1372	Castletown River	Cort Rd. Bridge	J0066509956					D	

Leinster, County Wexford

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1071	Sow River	Poulsack Bridge	T0480027000		D	D	D		
1074	Tintern Abbey Stream	Tintern Abbey	S7940010000	D	D	D			
1077	River Sow	Kilmallock Bridge	T0327031910						
1120	North Slob Channel	Channel - Wildfowl Reserve	T0827525539	D	D	D	D	D	D
1159	River Bann	Margerry's Bridge	T1144159337	D	D	D	D	D	D
1161	River Slaney	Scarawalsh Bridge	S9837545068	D	D				
1254	Slaney River	Enniscorthy Bridge	S9742239898			D	D	D	D
1294	Bann Upper	Laraheen	T1330064200					D	
1317	Ballyteige Channels	Ballyteige	S9400006000						D
1350	Unknown River	Castle Bridge, Baldwinstown	S9705010250					D	D

Leinster, County Offaly

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1076	River Shannon	Banagher Bridge	N0050015800		D	D		D	
1092	River Shannon	Lusmagh	M9666915225						
1129	River Brosna	Ballycumber Bridge	N2120030600	D	D	D	D		
1172	Grand Canal	Srah Castle	N3290025200	D	D	D	D		D
1174	Grand Canal	Griffith Bridge/Shannon Harbour	N0330019100	D	D				
1207	Clodiagh River	Muchlagh Bridge	N3100022800		D		D	D	D
1210	Silver River	Wooden Bridge	N1270014300		D		D		
1305	Gageborough River	John Halloway Farm	N2673337876				D		
1307	Grand Canal	Cartland Bridge	N5980032400				D		
1340	Gageborough River	Ballyboughlin Bridge	N2365033800				D		
1366	Grand Canal	Belmount	N0735921944					D	
1404	River Barrow	Portarlington	N5400012700						D
1422	Grand Canal	Killeen Bridge, Daigean							D

Leinster, County Kilkenny

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1078	River Nore	Knockanore	S5469643591	D	D	D		D	
1079	River Nore	NE of Warrington	S5373654466	D	D			D	
1080	River Nore	Threecastles Bridge	S4582162709	D	D	D	D	D	D
1082	River Barrow	Graiguenamanagh Bridge	S7072443544	D	D	D	D		
1185	Dinin River	Dinin Bridge	S4789062850		D				
1186	River Nore	Fennessys Mill	S5228754953		D	D	D	D	D
1202	River Nore	Dysart	S5960039300			D	D	D	
1238	Glory River	Monachunna Townland	S4810038100		D				
1239	Kings River	Ballycloven	S4853939873		D				
1242	Mountain River	Ballycoppigan Bridge	S7343549860		D		D		
1269	River Nore	Threecastles Bridge d/s	S4650062600			D			

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1287	Kings River	Kells Bridge	S4941543690		D			D	D
1303	River Nore	Kilkenny City	S5150055500					D	
1304	River Nore	Bennetsbridge North	S5524349272					D	D
1321	Kings River	Newtown	S4640043500					D	D
1351	River Nore	Lismaine Bridge	S4410566004					D	
1352	River Dinan	Corbettstown	S5060066200					D	D

Leinster, County Carlow

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1081	River Barrow	St. Mullins	S7295037800	D	D	D	D	D	D
1163	Douglas River	Cunaberry Bridge	S8422067950	D					
1184	River Barrow	Clashganey Lock	S7360945865		D	D		D	
1197	River Dereen	Acaun Bridge	S9000077900			D	D	D	D
1258	Slaney River	Kilcarry Bridge	S8940062500		D	D	D	D	D
1259	River Barrow	Ballyteiglea Br (Lock)	S6920053200		D			D	D
1383	Lerr River	Gotham Bridge	S7260082200						D
1386	River Barrow	Maganey Bridge	S7175084650						D
1387	River Barrow	Barrow Track, Carlow	S7173976826						D
1390	River Barrow	Slyduff	S6860057400						D
1392	River Barrow	Milford Bridge	S6970067100						D
1398	River Slaney	Tullow Bridge	S8490072200						D
1406	River Barrow	Clogrennan Bridge	S6980073700						D
1408	River Barrow	Leighlin Bridge	S6905065450						D
1409	River Barrow	Rathvinden Lock	S6960066400						D
1418	River Slaney	Slaney Bank Estate	S8770082300						D

Leinster, County Laois

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1179	River Erkina	Footbridge 0.5km u/s Durrow	N4050077500		D				
1181	River Nore	Waterloo Bridge	S4110084000		D			D	D
1182	Owenass River	Bridge Nth of Irishtown Hs	N4500007300		D		D		
1183	Delour River	Annagh Bridge	S2910093500		D				
1196	River Barrow	Portnahinch Bridge	N4910010100		D	D	D	D	D
1199	Vicarstown Canal	Vicarstown	N6150000500		D	D			
1228	Stradbally River	Stradbally Bridge	S5720096300		D	D	D	D	D
1309	Grand Canal	Courtwood Bridge	N6190004100				D	D	

Munster, County Clare

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1025	Inagh River	Inagh Bridge	R2082081290	D	D	D	D	D	D
1026	Inagh River	Moananagh Bridge	R1703084900	D					
1135	Errina-plassey Canal	Errina Bridge	R6400064800	D	D				
1137	Claureen River	Claureen Bridge	R3285978100	D	D	D	D	D	D
1138	River Fergus	Drehidnagower	R3301778654	D					D
1155	Owenocarney River	Annagore Bridge	R4768267717	D			D		
1166	River Fergus	Dromore Wood	R3592787828		D	D	D		
1216	Scarrif River	Cooleen Bridge	R6030086000		D	D	D		
1218	Scarrif River	1km u/s Scarrif Bridge	R6330084315			D	D	D	D
1316	River Shannon	O'Brien's Bridge	R6610066800				D		
1336	Bleach River	Flagmount	R5555094900				D		

Munster, County Tipperary

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1027	Mulkear River	Bridge Nth of Coolruntha	R8060068700	D	D	D	D	D	D
1063	River Suir	Knocklofty Bridge	S1450020628		D	D	D		D
1064	River Suir	Thurles Bridge	S1295758635		D				D
1069	Nenagh River	Tyone Bridge	R8770077900	D	D	D	D		D
1072	Suir River	Kilsheelan Bridge	S2862023234	D				D	D
1073	Suir River	Cabragh Bridge	S1119956062	D			D	D	D
1085	Clashawley River	Fethard	S2050034900		D	D	D		D
1089	River Aherlow	Cappa Old Bridge	R9935429318	D	D	D	D	D	D
1324	Mulkear River	Rockvale Bridge	R7381763391				D		
1027	Mulkear River	Bridge Nth of Coolruntha	R8060068700	D	D	D	D	D	D
1063	River Suir	Knocklofty Bridge	S1450020628		D	D	D		D

Munster, County Cork

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1049	River Lee	Bannon Bridge	W6131671632	D		D		D	D
1050	Martin River	Bawnafinny Bridge	W5979075412	D	D	D	D	D	D
1052	Owenboy	Priests Bar	W6049161227	D					
1053	River Foherish	Carrigaphooca Bridge	W2963673766	D	D			D	D
1054	Glashaboy River	Upper Glanmire Bridge	W7146478294	D	D	D	D	D	
1055	Shournagh River	Tower Bridge	W5862074551	D	D	D	D	D	D
1056	Laney River	Carrigagulla Bridge	W3894683016	D	D				
1057	Bride River	Coolmucky Bridge	W4603767916	D	D	D	D		
1058	River Lee	Drumcarra Bridge	W2955867786	D	D		D	D	D
1059	River Sullane	Linnamilla Bridge	W3113972814	D	D				
1060	River Blackwater	Charles bridge	W2481194404	D	D	D	D	D	D
1061	Argideen River	Lisselane Bridge	W4059944400			D	D	D	D
1087	Dripsey River	Dripsey Bridge Lower	W4612279628	D					D

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1091	Glengarrif River	Footbridge NW of Glengarrif	V9178756970	D	D	D	D	D	D
1099	River Blackwater	Careyville	W8558399508	D	D	D			D
1101	Arigideen River	Kilmaloda Bridge	W4519545566	D	D			D	D
1123	River Lee	Kennel's to Weir Stream	W5870071400		D			D	D
1187	Owenboy River	Ballea Bridge	W7090063300						D
1206	River Lee	Lee Fields	W6484371393			D	D		
1208	Dripsey River	Dripsey Bridge	W4876073864			D	D	D	D
1345	Butlerstown River	Glyntown Bridge	W7325075000				D	D	D
1361	Owenboy River	Bealahareach Bridge	W6846763224						
1377	River Bandon	Innishannon Bridge	W5420057100						D
1382	Leemara River	Leemara Wood	W9275875314						D
1394	Dungourney R.	Bilberry	W9275875314						D
1397	Shournagh River	Shournagh Cross Roads	W5910075400						D
1402	Allow River	Kilberrihert, Metal Bridge	R3940011800						D
1416	Bandon River	Dunmanway	W2280053000						D

Munster, County Kerry

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1062	Owenreagh River	Gearhamnen	V8842282104	D	D	D	D	D	D
1065	River Feale	Racecourse Footbridge	Q9808433646		D				
1066	Flesk	Flesk Bridge	V9672589468	D	D	D			D
1096	River Feale	Finuge Bridge	Q9511132113						
1097	Sneem River	Br u/s Ardsheelhane R. confl.	V6291667562	D					
1153	Feale River	Listowel Bridge	Q99526332922			D	D		
1226	Emlagh River	Bridge W of Emlagh townland	Q6480003300						
1263	River Laune	1/2km below Beaufort Bridge	V8816692633		D	D	D		
1276	Blennerville Canal	Blenerville	V8164713313			D	D	D	D
1298	Owenascaul River	Anascaul Bridge	Q5920001900					D	D
1313	River Lee (Kerry)	Ballyseedy Wood	Q8760113092					D	D
1328	River Maine	Castleisland	R0015109561					D	

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1337	River Lee (Kerry)	Tralee Town	Q8371913759					D	D
1368	Maine River	Maine Bridge	Q8909004815					D	D
1373	Cashen River	Ferry Bridge	Q8890036500					D	

Munster, County Waterford

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1075	Whelan's Br River	Whelan's Bridge	S5220009900	D					
1084	Owennashad River	Br u/s Blackwater R. confl.	X0482098940	D	D	D	D	D	D
1107	Whelan's Br River	Br West of Carrickduston	S5075007600						
1117	River Suir	Suir Valley Railway	S5390010400		D	D			
1151	St. John's River	Kilbarry Walkway	S6015010000			D	D		
1162	Colligan River	Colligan Bridge	X2195897983		D				
1167	Twomile Bridge	River Blickey	X2250091200			D	D	D	D
1200	Dalligan River	Ballyvoyle Bridge	X3359794997					D	D
1233	River Bride	Tallow Bridge	W9980094400		D				
1237	Mahon River	Aughshemus Bridge	S4160002600			D	D	D	D

Munster, County Limerick

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1103	Maigue River	Fort Bridge	R5060025700				D		
1136	Greanagh River	Coolah Bridge	R4434946357						
1139	River Barnakyle	Old Forge Bridge	R5103853043						
1154	Mulkear River	Annacotty Bridge	R6430057700	D		D	D	D	
1156	Bilboa River	Gortnagarde Bridge	R7800050500	D	D	D	D	D	D
1178	Feale River	Mount Colums Creamery	R1575018700			D	D	D	D
1342	Mulkear River	Abington	R7157653428				D	D	
1349	Killeenagarrif River	Barrington's Bridge	R6789054928					D	
1389	River Maigue	Ballycasey, Kildimo	R4690050600						

Ulster, County Derry

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1070	Moyola River	Curran Bridge	H9520089500	D			D	D	D
1105	River Roe	Dog Leap	C6790020300	D	D		D	D	D
1106	River Roe	Dungiven Bridge	C6830009800	D	D		D	D	D
1244	River Faughan	Park Bridge	C5910002400			D	D	D	D
1246	Lower Bann	The Cuts	C8560030300			D	D	D	
1253	Aghadowney River	Agivey Bridge	C8980022900			D	D	D	D
1272	River Roe	Roe Road Bridge	C6680022900			D	D		D
1280	River Faughan	Faughan Bridge u/s	C4930020600			D	D		
1281	Aigivey River	Errigal Bridge	C8130014500			D	D	D	D
1290	Agivey River	Moneycarrie Bridge	C8670019500			D	D	D	
1364	Unknown River	Whitehouse, Ballymagrorthy	C3990018800				D	D	

Ulster, County Antrim

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1102	River Lagan	Shaws Bridge	J3250069000	D	D			D	D
1104	Mascosquin River	Ree Bridge	C8981628667	D	D		D	D	
1108	Glenarm River	Glenarm Estate	D3012511916	D	D	D	D		
1175	Lagan Canal	Hilden Bridge	J2810065500					D	
1192	River Bush	Bush Golf Course	C9370042500			D	D	D	D
1229	Glenarm River	Glenarm Castle	D3100015100			D	D		
1231	River Lagan	Drum Bridge	J3060067100		D		D		D
1241	River Bush	Conagher Bridge	C9574930521			D	D	D	
1245	Sixmile Water	Loughshore Park	J1480086500			D	D	D	D
1260	Sixmilewater	Millrace Trail	J1550085500			D	D	D	D
1266	River Lagan	Stranmillsweir to Lagan Meadows	J3410070900		D	D	D	D	D
1267	Sixmilewater	Castlefarm Bridge	J1440086800		D	D			
1289	River Lagan	Wolfden's Bridge	J2847668805			D			

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1291	Lagan Canal	Ballyskeagh High Bridge	J2880066900			D		D	D
1325	Lagan Canal	Moore's Bridge	J2803064650						D
1326	Lagan Canal	Lock Keepers Cottage	J3300069100					D	D
1388	Crumlin River	Lennymore Blue Bridge	J1190075300						D
1393	Lagan Canal	Broadwater	J1480062700						
1396	Lagan Canal	Gilchrest Bridge	J3172968037						D
1407	Sixmile Water	Dunadry Rd, Muckmore	J2010085000						D

Ulster, County Armagh

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1109	Cusher River	Clare Glen Bridge	J0140043900	D	D		D	D	D
1110	Newry/Bann Canal	Moneypennys Lock	J0330051200	D	D	D	D		
1111	Bann (Newry) Canal	Scarva Heritage Centre	J0640043700				D		D
1223	Newry Canal	Victoria Lock	J0960023400		D	D		D	D

Ulster, County Down

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1112	Moneycarragh River	Moneylane	J3990036900	D	D				
1113	Ravernet River	Legacurry Bridge	J2970060100						
1224	The Quoile	Quoile Pondage	J4960047000			D	D		D
1268	River Bann	Lawcencetown	J0990049200		D				D
1278	Crawsfordsburn River	Crawsfordsburn Country Pk	J4670082000		D				D
1292	Enler River	Dundonald	J4230073200						
1362	Newry Canal	Campbell's Lock	J0640045100					D	
1363	River Coyle	Stoneyford	J5830048900				D		
1403	Glasswater	Glasswater	J4495054050						
1410	Shimna River	Tollyforest	J3270031900						D

Ulster, County Cavan

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1133	River Blackwater	Nine Eyes Bridge	N6304083380	D	D	D	D	D	D
1141	River Blackwater	Killryan Bridge	H2025014600	D	D	D	D	D	D
1188	Woodford River	Ballyconnell Town	H2729118609					D	D
1189	Cladagh River	Swanlinbar Church of Irl	H1940027200					D	
1248	Annalee River	Rathkenny Bridge	H5350011600		D		D	D	
1273	Annalee River	Butler's Bridge	H4094910499			D	D	D	D
1318	Virginia River	Handball Alley, Virginia	N6050087600						D
1355	River Erne	Erne Bridge, Belturbet	H3514117039				D	D	D

Ulster, County Monaghan

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1134	Monaghan Blackwater	New Mills, Cornahoe	H7189838769			D		D	
1261	Ulster Canal	Monaghan Town	H6800034700						
1297	Clarebane River	Clarebane Bridge	H8740016800				D		

Ulster, County Donegal

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1148	Owenea River	Owenea Bridge	G7369092110	D	D	D	D	D	
1149	River Deele	Milltown Bridge	C2450099613	D		D			
1164	Crana River	Crana Park	C3480432892	D					
1277	Lackagh River	Lackagh Bridge	C0956930880		D				
1319	River Finn	Drumboe Woods	H1351294675					D	
1346	Leannan River	Claragh Bridge	C2045020300				D	D	D
1367	River Eske	Donegal Town	G9285878608					D	D

Ulster, County Fermanagh

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1168	Kesh River	Kesh	H1820064200	D	D			D	
1169	River Erne	Enniskillen	H2700053000	D	D	D	D	D	D
1170	Colebrook River	Ballindarragh Bridge	H3310036000	D		D	D		
1265	Sillees River	Glencunny Bridge	H0830038400		D	D	D	D	
1279	River Shrule	Stone Bridge u/s	H4369577631			D			D
1302	Arney River	Borchagh Bridge	H1750037500					D	
1354	Woodford River	George Mitchell Peace Bridge	H3395819357					D	D
1360	Colebrook River	Ashbrook/Scarford Br	H3914144098				D	D	D

Ulster, County Tyrone

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1033	Coalisland Canal	Moor Bridge	H8590065000					D	D
1230	Camowen River	Lover's Retreat Picnic Site	H4680072900			D	D		
1235	Fairywater	Downstream of Poe's Bridge	H4250075000			D			
1243	Camowen River	Bracky Bridge	H5350071400			D	D		D
1247	Glenelly River	Drumaspar	H4960091300			D			
1264	River Strule	Stone Bridge	H4370077600		D	D	D		
1282	Fairy Water	Omagh	H4290074900		D				
1288	Drumragh River	Lissan Bridge	H4660070100			D			
1359	Blackwater River	Favour Royal Bridge	H6121753031				D	D	D
1378	Ballinderry River	Kildress AC	H7730078400						D
1384	Ballinderry River	Cabinwood	H8160076500						D
1385	Killymoon River	Tullylagan Manor	H8020073000						D
1391	Ballinderry River	Scotstown Road	H9440080600						D
1411	Ballinderry River	Coagh Village	H8920078700						D
1412	Ballinderry River	Artrea Canoe Steps	H8609076900						D

Connaght, County Galway

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1014	Streamstown River	Interpretative Centre	M4807005685	D	D	D	D	D	D
1015	Clarinbridge River	Clarin Bridge/Cowpark Commonage	M4123420005	D	D	D		D	D
1016	Black River	Moyne Bridge	M2500049000	D	D	D	D	D	D
1017	Lough Kip River	Dr. Chlaidhdi	M2221531223	D	D				
1018	Owenriff River	Glan Road Bridge	M1224443146	D	D	D	D	D	D
1019	River Corrib	Salmon Weir Bridge	M2959225666	D		D			D
1020	Kilcolgan River	Dunkellin Bridge	M4420218423	D		D			
1021	Cregg River	Addergoole Bridge	M3228334994	D	D				
1022	Clare River	Claregalway Bridge	M3717933228	D	D	D	D	D	D
1043	Rafford River	Ratty's Bridge	M5473423259	D	D				
1160	Rafford River	Rafford House	M6083726048	D	D	D			
1180	River Suck	Ballyforan Bridge	M8160046300			D	D		
1195	Gort River	Castletown Mill	M4583303174		D		D	D	D
1205	River Knock	Knockadrohid Bridge	M1587926695		D				
1262	Corrib River	Quincentennial Bridge	M2928726328						
1270	Dawros River	Derryinver Bridge	L7000059000			D		D	
1312	Kilcrow River	Hearnesbrook Demesne	M7999011970						
1370	Owenglin River	Andbear Old Bridge, Clifden	L6600050400					D	D
1415	Kilcrow River	Ballyshrule Bridge	M7970005600						D
1420	Dooyertha River	Clougharevaun Bridge	M5830024400						D
1421	Unknown River	Lisduff Townland	M6440020400						D

Connaght, County Mayo

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1028	River Moy	Mount Falcon Fisheries S1	G2494413324			D			
1095	Cartron River	Carran	F8001100176						
1124	Manulla River	Belcarra Walkway	M2010085400	D		D			

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1150	Owenwee River	Belclare Bridge	L9599882163	D	D	D			
1171	River Robe	Crossboyne Bridge	M3386170962						
1190	Owengarve River	Rosgalive Bridge	L8866096312						
1191	Carrowbeg River	2nd br u/s lake, Westport Hs	L9940484624		D	D	D	D	D
1198	Castlebar River	Castlebar Town	M1400090500			D		D	
1369	River Robe	Ballinarobe Town	M1903264544					D	D
1376	Newport River	Newport Town	L9900094000					D	D
1399	River Cloughmore	Palmerstown	G1730031500						D
1400	Owenmore River	Bangor Erris Village	F8610022800						
1401	Deel River	Unknown	G1780018900						D
1405	Owenmore River	Bellacorick Bridge	F9690020000						

Connaght, County Leitrim

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1115	Drowse River	Lennox's Bridge	G8180857254	D	D	D	D	D	D
1121	Duff River	Bridge at Drumacolla	G7960049100	D	D	D		D	
1144	Diffagher River	Cloonemeohe Bridge	G9345124542	D	D	D	D	D	D
1145	River Shannon	Dowra Bridge	G9910026700	D					
1358	River Bonet	Drumlease Fileds	G8184830233				D	D	D
1417	Shannon Erne Waterway	Ballyduff Bridge	H197109						D

Connaght, County Sligo

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1051	Unshin River	Colloney	G6793026563						D
1114	Owenmore River	Big Bridge	G6662412322		D	D	D	D	D
1118	Owenmore River	Templehouse Bridge	G6250918568	D	D	D	D	D	D
1119	Drumcliff River	Ford 500m u/s Drumcliff Bridge	G6823242240	D	D	D			
1152	Unshin River	Ballygrania Bridge	G6949725875	D	D	D	D	D	D
1176	Clooneen River	Bridge NW of Kilavil	G6364110056						
1194	Unshin River	Riverstown	G7399720147		D				

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1320	Garvogue River	Bridge Street, Sligo	G6930935969					D	D
1322	Owenmore River	Knoxpark	G6735028950				D	D	D
1323	Ardnaglass River	Ardnaglass Bridge	G5310034300						

Connaght, County Roscommon

Site Code	Waterway	Site Name	Grid Ref	2006	2007	2008	2009	2010	2011
1122	Boyle River	Knockvicar Bridge	G8728605541	D	D	D	D		
1146	River Shannon	Mahanagh Bridge	G9557611687	D	D	D	D	D	D
1147	River Suck	Castlecoote Bridge	M8086362621	D	D	D			
1157	Boyle Canal	Boyle Canal	G8200004300	D	D	D			
1158	Lung River	Br u/s Lough Gara	M6614696681	D	D	D	D		
1327	Hind River	South of Roscommon Town	M8935061350				D		
1329	River Suck	Conamon Bridge	M7895064900				D	D	D
1330	River Suck	Rookwood Bridge	M8095057600				D		
1331	Boyle River	Boyle Town	G7940502494				D	D	
1332	Lecarrow Canal	Lecarrow	M9715055500				D	D	D
1333	River Suck	Cloondacarra Bridge	M6710078050				D		
1334	River Shannon	Roosky	N0539787001				D	D	D
1335	River Scramogue	Carrowclogher	M9290078100				D		
1339	River Shannon	Tharmonbarry	N0550076950				D		
1347	Shannon Channel	Bigmeadow, Athlone	N0391740202						

Appendix III

Survey Recording Sheet Page 1

All Ireland Daubenton's Bat Waterway Survey - Survey Form

Grid reference of site:	**Surveyors names:**
Water way name:	**Address:**
Site name:	
Is the site a SAC:	
Is the site a NHA/SSSI:	**Tel no.:**
Bat model detector used:	**Email:**

My length of field experience with a bat detector is: (please circle one)
Less than 1 yr / 2-3 yrs / >3 yrs

My bat identification skills are: (please circle one)
Poor / OK / Good / Very good

Survey 1 (1^{st}-15^{th} August)				**Survey 2 (16^{th} – 31st August)**			
Date:				**Date:**			
Start Time:		**Finish Time:**		**Start Time:**		**Finish Time:**	
Temp (°C):		**Wind** (circle one)	Calm Light Breezy	**Temp (°C):**		**Wind** (circle one)	Calm Light Breezy
Cloud (circle one)	Clear (0–1/3) Patchy (1/3-2/3) Full (3/3)	**Rain** (circle one)	Dry Drizzle Light rain	**Cloud** (circle one)	Clear (0–1/3) Patchy (1/3-2/3) Full (3/3)	**Rain** (circle one)	Dry Drizzle Light rain

Number of Bat Passes			**Number of Bat Passes**		
Spot	**Daubenton's bat**	**Unsure Daubenton's bat**	**Spot**	**Daubenton's bat**	**Unsure Daubenton's bat**
1			1		
2			2		
3			3		
4			4		
5			5		
6			6		
7			7		
8			8		
9			9		
10			10		

Waterway Characteristics

What % of waterway is sheltered by trees or overhanging vegetation?
None ☐ up to 50% ☐ greater than 50% ☐

How much of the waterway surface that is calm/smooth?
None ☐ up to 50% ☐ greater than 50% ☐

Approximate width of majority of waterway ________m
Number of spots with a clear view of the water ________

Thank You for your very valuable contribution to this monitoring programme.

Please return your completed form to:
Dr Tina Aughney, BCIreland, Ulex House, Drumheel, Lisduff, Virginia, County Cavan

Type of bridge at grid referenced point: traditional stone bridge ☐ modern concrete bridge ☐
Other (please describe) ____________________

Please note other wildlife: Otter__ Barn owl __ Long-eared owl __ Other ____________

Survey Recording Sheet Page 2

Please note your spot descriptions below. Try to use permanent features where possible; remember dead trees and such features are often removed. Please gain permission to enter land prior to survey.

Spot	Spot Description	Landowner details
1		
2		
3		
4		
5		
6		
7		
8		
9		Only fill in this page if details differ from previous years.
10		

Access / Parking Notes & Additional Notes

WHERE POSSIBLE, PLEASE MARK SURVEY SPOTS ON OS MAP PROVIDED OR ON 6 INCH OR 21 INCH MAPS OF YOUR WATERWAY SITE (AVAILABLE FROM YOUR LOCAL LIBRARY) AND RETURN WITH THIS FORM.

Spot	Habitat Description please √ if any of the following are present at within 10m of survey spots on the nearside of the river bank (where survey spot is located) or the far-side of river bank (opposite side of the river bank)						Street Lighting Please circle Yes/No if lighting from street lamps or lighting on adjacent buildings/bridge is shining onto the waterway at each of the individual survey spots.
	Trees		Hedgerow		Tall reeds/grasses		
	Nearside	Farside	Nearside	Farside	Nearside	Farside	
1							Yes / No
2							Yes / No
3							Yes / No
4							Yes / No
5							Yes / No
6							Yes / No
7							Yes / No
8							Yes / No
9							Yes / No
10							Yes / No