DWR-1108

EirGrid Evidence Based Environmental Studies Study 3: Bats

Literature review and evidence based field study on the effects of high voltage transmission lines on bats in Ireland

December 2015

EIRGRID
The current. The future.

This document has been prepared by EirGrid plc with the assistance of RPS Group.

The evidence contained in this study has been provided by RPS Group.

Reproduction of this study is authorised provided the source is acknowledged.

December 2015

SUMMARY

Bats are mammals, and their ecology (meaning the relationship between animals, plants and their environment) is dependent upon suitable habitats existing within the landscape. Suitable habitats include woodlands, hedgerows, ponds, caves and stone buildings. Conserving these habitats is therefore important for bat ecology, because they enable bats to forage for food, to roost, to hibernate, and to successfully breed.

This study, undertaken for EirGrid by experts in bat ecology from RPS Group examines the effects of the construction and operation of high voltage electricity transmission projects on bat activity in Ireland.

The purpose of this study is to:

- Conduct a review of studies and other literature on the potential impact on bats arising from the development of electricity transmission infrastructure. This includes impact arising from electromagnetic fields (EMFs), and the risk of collision and electrocution;

- Determine the effects of the construction and operation of existing electricity transmission infrastructure on bat activity;

The study looked at how bats use the landscape, and if electricity transmission infrastructure affects bat activity in Ireland. Our review found very little in the literature related to the possible direct effects of electricity transmission infrastructure on bats.

However, studies do highlight the importance of hedgerows and trees to bats for feeding and navigation in flight. Construction of overhead lines may impact on hedgerows and trees. Therefore the possible indirect effects of habitat alteration, is a focus of the study.

For this study, a programme of field surveys was also undertaken at over 80 separate sites across Ireland, from June 2012 to September 2012. Two types of bat surveys were conducted: the first involved driving a car along roads and laneways where an

overhead line (OHL) followed the road or lane, and using specialist bat recording equipment; the second involved placement of automatic recording equipment at locations where pylons were located in or near to hedgerows. Half of these locations were in “managed” hedgerows (i.e. where hedgerows are regularly cut by a landowner), and the other half were located in “unmanaged” hedgerows.

Both sets of surveys focused on confirming whether bat activity was present or absent near the existing transmission infrastructure. The monitoring at hedgerows also aimed to assess if there are any differences in the likelihood of a bat species being present at the two different hedgerow types (managed and unmanaged).

Survey results indicate that there was no significant association between likelihood of bat occurrence and distance from power lines of any voltage (110kV, 220kV and 400kV). Based on this, it can be concluded with some confidence that power lines do not have a deterrent effect on the more common resident Irish bats while in flight.

Six of the study sites demonstrated a long-term or permanent loss of shrub/tall tree component ≥10m. In all cases some smaller scrub-like vegetation with brambles and grasses had grown along the line of the former hedgerow. Despite the break in the shrub/tall tree component at these sites, bats were recorded at all of them. The extent of hedgerow removed was notable at two sites where infrastructure had been recently erected. However, bats were still recorded despite a new and considerably elongated break in shrub/tall tree component.

The presence of bats at these locations would indicate that bat flight is not prevented by breaks in hedgerow required for the construction of pylons.

The results of this evidence-based study on the effects of transmission infrastructure on bat activity in Ireland, have established that best practice in the development of electricity transmission infrastructure should ensure:

- the use of habitat/species sensitive construction methods;
- the avoidance of linear features such as treelines and hedgerows where possible with replanting/replacement where disturbance is unavoidable:

- the enhancement of local linear vegetation with supplementary native planting where suitable and appropriate ;

- the engagement of a suitably qualified ecologist from the design stage through to site construction with input from a bat specialist where required.

This study has provided a factual basis for a future review and update of EirGrid’s Ecology Guidelines. This will ensure a consistent and standardised evidence-based approach to the impact assessment of bats at all stages in the development of transmission projects.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

ABBREVIATIONS

AMF	Alternating Magnetic Field
BCI	Bat Conservation Ireland
BCT	Bat Conservation Trust
CORINE	Coordination of Information on the Environment
EC	European Communities
EIA	Environmental Impact Assessment
ELF	Extremely Low Frequency
EMF	Electromagnetic Field
ESB	Electricity Supply Board
GIS	Geographic Information System
HVETI	High Voltage Electric Transmission Infrastructure
IF	Intermediate Frequency
LHS	Lesser Horseshoe
NIR	Non-Ionising Radiation
NPWS	National Parks & Wildlife Service
OHL	Overhead Power Line
RF	Radio Frequency
RFR	Radio Frequency Radiation
SEA	Strategic Environmental Assessment
Spp.	Species (plural)

1 INTRODUCTION

1.1 THE SCOPE OF THIS PROJECT

In April 2012, EirGrid published the *Grid25 Implementation Programme 2011-2016*, and its associated Strategic Environmental Assessment (SEA).

The SEA identified a number of Environmental Mitigation Measures envisaged to prevent, reduce and, as fully as possible, offset any significant adverse impacts on the environment of implementing the Implementation Programme.

Environmental Mitigation Measure (EMM) 3 concerns *Preparation of Evidence-Based Environmental Guidelines*. These are intended to comprise a series of authoritative studies examining the actual effects of the construction and existence of transmission infrastructure in Ireland. The studies would thereby provide benchmarks to facilitate the robust preparation of projects with an evidence-based understanding of likely environmental impact.

Three types of studies are envisaged under EMM3:-

- **Environmental Benchmarking Studies**: to determine the actual effect, in respect of a number of environmental topics, of the construction and existence of transmission projects in a representative range of Irish environmental conditions – typical, non-standard, and worst-case. The studies, while authoritative, are conceived as an ongoing body of work that can be continuously updated to take account of new information and/or developments in understanding arising from practice and research;

- **Evidence-based Environmental Design Guidelines:** deriving from the factual basis and evidence contained in the initial Benchmarking Studies, these will provide practical guidance to practitioners and consultants in the planning and design of transmission infrastructure from the perspective of a particular environmental topic. These might comprise new guidelines, or the updating of existing guidelines;

- **Guidelines on EIA for Transmission Projects in Ireland:** Accompanying, or incorporated into the Design Guidelines, these are intended to provide an agreed and authoritative format for the preparation of EIA for transmission projects in Ireland, again in respect of particular environmental topics.

This Study is one of the Environmental Benchmarking Studies – to determine the actual effect of the construction and existence of transmission infrastructure in Ireland on its receiving environment.

1.2 THE AIM OF THIS STUDY

The aim of this evidence-based environmental study is to determine the effects, if any, of the construction and operation of existing high voltage electricity transmission infrastructure on bat activity in Ireland.

There are nine species of bat known to commonly occur in Ireland[1] and all are protected species listed under Annex IV of the Habitats Directive (92/43/EEC)[2]. Bat species are also protected in Ireland under the Wildlife Act 1976 and the Wildlife (Amendment) Act, 2000.

Given the subject matter of this study, the high voltage electricity transmission projects considered herein primarily include 400kV, 220kV and 110kV overhead lines (OHLs), including supporting tower and poleset structures. The comparative impacts of underground cables (UGCs) are also discussed in the literature review.

OHLs are typically constructed across agricultural lands as this is the primary land use in Ireland. Based on the issues that could be relevant to bat species in Ireland in relation to effects of existing electricity transmission system, and the planned further development of the transmission system, the following questions were developed for this Study:

Question 1: Does the scientific literature provide evidence that the presence of high voltage overhead transmission lines, including associated electromagnetic fields, have an effect on bats?

Question 2: Does the presence and operation of high voltage overhead transmission lines impact on bat activity in the natural environment?

[1] Common pipistrelle *Pipistrellus pipistrellus*, Soprano pipistrelle *P pygmaeus*, Nathusius pipistrelle *P. nathusii*, Leisler bat *Nyctalus leisleri*, Daubentons bat *Myotis daubentonii*, Natterer's bat *M. nattereri*, Whiskered bat *M. mystacinus*, Brown long-eared bat *Plecotus auritus*, Lesser horseshoe bat *Rhinolophus hipposideros*

[2] The Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora; consolidated in the European Communities (Birds and Natural Habitats) Regulations, 2011

1.3 THE TRANSMISSION NETWORK AND BATS

Electricity supply is an essential service in Ireland's economy. The transmission system is a meshed network of 400 kV, 220 kV and 110 kV high voltage lines and cables and plays a vital role in the supply of electricity[3].

The development of the transmission network is the responsibility of EirGrid, the Transmission System Operator (TSO) under statutory instrument 445 (2000)[4]. EirGrid is committed to delivering quality connection, transmission and market services to its customers and to developing the transmission grid infrastructure required to support the development of Ireland's economy.

Grid development requires a careful balance between meeting the technical requirement for a project, the costs of that project, and the environmental impact of that project.

ESB, as the Transmission Asset Owner (TAO), is charged with constructing the transmission assets as specified by the TSO. ESB also has the role of Distribution System Operator (DSO) with which the TSO coordinate planning and development requirements.

An overview of the primary types of transmission infrastructure, including an outline of construction methodology is set out in **Appendix A** of this study.

Batsare an important element of our native biodiversity. However, increased development and an increasing population have placed competing pressures on Ireland's natural environment. Drivers for these competing pressures are varied and have sometimes been guided and assisted by government policy, incentives and grant schemes. Those pertaining to agriculture and infrastructure development in particular are driven by government policies, some of which are influenced in turn by EU policies such as the Common Agricultural Policy, EU Energy Policies etc.

The EU through its environmental law '*acquis communautaire*'[5] has imposed obligations upon each Member State to ensure a certain level of environmental protection. In particular the EU Habitats Directive[6], together with the Birds Directive[7] form the cornerstone of the EU's nature conservation policy, which must be adhered to by every Member State. Accordingly, the Irish State and its agencies have the responsibility for identifying, protecting, maintaining and preserving protected species and habitats, which includes bats and their habitats. In this context, EirGrid as the statutory agency responsible for the development of transmission infrastructure projects has published Ecology

[3] Transmission Development Plan 2008-2012 EirGrid
[4] Statutory Instrument 445 (2000), entitled European Communities (Internal Market in Electricity Regulations, 2000)
[5] This is the accumulated legislation, legal acts and court decisions in relation to environmental protection built up by the EU over the past number of decades.
[6] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora
[7] Directive 79/409/EEC as amended

Guidelines[8] in the planning and development of those projects. The findings of this study will inform the updating of these guidelines.

The potential effects of transmission infrastructure development on bat ecology relate primarily to the potential for temporary and/or permanent habitat loss and fragmentation during construction. This may lead to the damage or destruction/removal of bat roost sites, foraging sites and transit routes. In addition, the routing of an overhead transmission line can potentially continue to affect bat foraging and/or transit routes across the local landscape.

This applies to both known and previously unknown features associated with bat ecology. Under Irish wildlife legislation, it is illegal to deliberately capture or kill bat species or deliberately disturb bat species during breeding, rearing, hibernation and migration. It is also illegal to deliberately damage or destroy a resting or breeding site. It is also an offence to injure or wilfully interfere with or destroy the breeding or resting place of bat species[9].

The significance of the effects on bat ecology depends on the location and scale of the proposed infrastructure and potential for screening and mitigation measures. This is why the design of any proposal for transmission infrastructure development should be informed by a suitably qualified bat specialist. This is also the case as a project progresses to construction.

1.4 STUDY LAYOUT

Section 2 provides a literature review which addresses Question 1 as referred to in Section 1.2 above. It presents sources of scientific information explaining how bats use the landscape, where they roost, hibernate and forage, and how they commute. Several bat studies are referred to that provide evidence of positive associations between bat activity and insect activity and varying associations across bat species to linear features including hedgerows.

Section 2 also refers to information on the potential impacts from the construction and operation of transmission infrastructure on bat ecology. No peer reviewed studies are available on the effects of low frequency EMFs on bats; reference is therefore provided to EMF studies on other animals and birds. Similarly, as there is no peer reviewed information on bat collisions or electrocutions with OHLs, wind turbine collisions are referred to. Section 2 concludes with reference to the variables potentially affecting bat surveys and the difficulty in determining reasons for any decreased bat activity at OHLs.

The bat surveys used to determine bat activity in the vicinity of OHLs are detailed in Section 3. This section presents the bat survey methodology, with detailed information provided on site selection methodology, for both driven transect and passive monitoring surveys.

---

[8] EirGrid (2012): Ecology Guidelines for Electricity Transmission Projects. EirGrid, Dublin
[9] The Wildlife Act 1976 and The Wildlife (Amendment) Act, 2000

Section 4 presents the results of the surveys, and focuses on answering two key questions. A) Does the literature review provide evidence of effects on bats from OHLs. B) Does the presence and operation of transmission infrastructure impact on bat activity in Ireland?

Section 5 presents a discussion of the results. Bat activity in the vicinity of transmission infrastructure is examined. The importance of linear features within the landscape to bat ecology is also highlighted. Section 6 provides recommendations to inform ecological impact assessment and mitigation within the planning, consenting and EIA regime and construction stage techniques in respect of bat ecology.

2 LITERATURE REVIEW

Section 2.1 of this review, *The Use of the Landscape by Bats,* is used to provide context to the main review, *The Potential Effects of Electricity Transmission Infrastructure on Bats* (Section 2.2).

2.1 THE USE OF THE LANDSCAPE BY BATS

Within the Irish landscape, individual bats use a network of roosting sites, often in built structures but sometimes in trees or natural caves. These are connected to a suite of habitats for foraging that are located within range of the roost site. During autumn, some bats, particularly the *Myotis* spp., swarm in caves (a behaviour that is thought to be related to mating). Individuals may travel long distances, even across mountain ranges, to favoured swarming sites.

Irish bats hibernate in winter. Little is known about hibernacula for most Irish bats, although some species have been found in small numbers in buildings or trees in winter, while the lesser horseshoe bat is mainly found in underground natural or artificial cave-like habitats.

Most Irish species, except the Leisler's bat, tend to fly along linear landscape features such as hedgerows and tree lines when commuting from roost to foraging site and vice versa.

Each of the nine species of Irish bats have differing morphologies, flight characteristics and echolocation styles. They use a varied suite of habitat types for foraging as well as having specific roost requirements (refer to Table 2.1, based on Lundy *et al.* 2011 and Marnell *et al.* 2009). For example, Daubenton's bat *Myotis daubentonii* has a strong association with waterways, whereas the brown long-eared bat *Plecotus auritus* is strongly associated with woodland and parkland. Differences are more subtle between similar or cryptic species such as common and soprano pipistrelles (*Pipistrellus pipistrellus* and *P. pygmaeus*).

Table 2.1: Broad Characteristics of Irish Bat Species

SPECIES	ABUNDANCE & DISTRIBUTION	CONSERVATION STATUS IN IRELAND	ROOSTS (Summer)	ROOST HABITAT	HABITAT ASSOCIATIONS
Common pipistrelle	Widespread, abundant although less so in the extreme north and west.	Least concern	Mainly buildings, prefers stone construction. Is sometimes found in trees[10]	Close to pasture.	Hedgerows, treelines, woodlands and riparian habitats.
Soprano pipistrelle	Widespread, abundant, less frequent across mountain ranges.	Least concern	Mainly buildings. Can be present in very large numbers +1000 in summer. Prefers brick construction. Is occasionally found in trees[1]	Close to woodland and freshwater	Hedgerows, treelines, woodlands, riparian and wetlands
Nathusius' pipistrelle	Locally common in Northern Ireland, rare elsewhere.	Least concern	From limited records it appears to favour stone constructed buildings[1].	Unknown	Freshwater habitats and broadleaf woodland.
Leisler's bat	Widespread, frequent. Less abundant in extreme north and extreme south west.	Near threatened (assigned this status due to importance of Irish population)	Favours stone constructed buildings with roofing felt. Also found in trees.	Close to broadleaf and mixed woodland and riparian habitats.	Mixed habitats, shows associations with woodland and riparian habitats.
Daubenton's bat	Widespread, frequent.	Least concern	Favours uninsulated stone structures such as bridges and ruins.	May roost close to bog, marsh, heath.	Mainly associated with water although will forage in woodland.
Natterer's bat	Widespread, uncommon.	Least concern	Preferences not widely understood in Ireland.	Close to broadleaf woodland, mixed woodland and scrub.	Woodland, mixed woodland, riparian habitats and small areas of pasture.
Whiskered bat	Uncommon or rare, restricted distribution with southerly bias. Occurs in low numbers.	Least concern	Prefers stone buildings.	Close to broadleaf woodland, mixed woodland and scrub.	Woodland, mixed woodland, riparian and small areas of pasture & scrub.
Brown long-eared bat	Widespread, frequent although less so in Northern Ireland.	Least concern	Favours churches or stone buildings. Can be found in trees.	Close to broadleaf habitat and scrub.	Broadleaf woodland, mixed woodland, riparian habitats.
Lesser horseshoe bat	Locally frequent in six western counties. Absent elsewhere.	Least concern	Favours stone construction and avoids occupied dwelling houses. Very rarely in trees.	Close to broadleaf woodland. Avoids bogs and areas of mixed agriculture	Broadleaf and mixed woodland.

Source: based on Lundy *et al.* 2011 and Marnell *et al.* 2009.

[10] N.Roche pers.comm.

In a recent study, Lundy *et al.* (2011) aimed to provide a guide to the landscape associations and habitat requirements of bat species in Ireland. Existing bat records from the Bat Conservation Ireland (BCI) database, together with information on variables such as land cover, altitude, climate and other information were analyzed. The study identified the broad-scale geographical occurrence of each bat species and summarised the associations that caused these patterns.

The result of the study was a series of maps illustrating the geographical areas suitable for each bat species, including identification of *'Core Favorable Areas'* where the occurrence of each species may be expected.

This landscape modelling by Lundy *et al.* showed that broadleaved woodland is universally favoured by all Irish bat species. Also most species often have positive associations with mixed woodlands and riparian habitats. Small amounts of urban cover can also be a positive determinant for some species.

However, the Lundy *et al.* study was carried out at a relatively broad landscape scale using the CORINE (2006) dataset. Currently, the CORINE dataset does not account for small scale variations in Irish habitats or account for the importance of the network of linear features or hedgerows.

Bat activity is strongly correlated with insect density; therefore any reduction in insect density would be expected to result in a concurrent reduction in bat activity (Hayes, 1997; Racey *et al.*, 1985). Bats are associated with areas where insect density is high such as in woodland, woodland edge, tree lines, hedgerows and riparian habitat.

In Ireland the rural landscape includes an extensive network of connecting linear habitats including hedgerows and treelines (NPWS, 2008). These features are common in agricultural landscapes and many European bat species are closely associated with such features which provide an abundance of invertebrates for foraging, provide commuting routes between roost sites and foraging areas, and provide shelter from the elements and potential predators.

In Britain, bat activity (mainly pipistrelle spp.) is positively associated with hedgerows in all pastoral land classes. Linear features provide benefits to bats independent of their role as potential commuting corridors (Walsh & Harris, 1996).

The presence of hedgerow trees affects the use of linear features by some bat species in Britain (Brandt *et al.*, 2007; Boughey *et al.*, 2011). In a study in England, Brandt *et al.* (2007) found that the presence of a certain tree type, in this instance pedunculate oak *Quercus robur*, may determine levels of bat activity. Higher numbers of insects are associated with this tree species (Sterry, 2007).

The strength of association between bats and linear features varies among species (Verboom & Huitema, 1997; Boughey *et al.* 2011). The physical characteristics of that feature and proximity to other available habitats are also factors. Taking hedgerow as an example, hedgerow width, tree density and proximity to other available habitats such as a woodland or watercourse are important considerations. Boughey *et al.* (2011) in a UK study, suggest that hedgerows without trees, are mainly used by soprano pipistrelle *P. pygmaeus 'when other higher quality habitats are unavailable'* (in their case, a woodland patch).

In Ireland, pipistrelle bats *Pipistrellus* spp. forage and commute along to linear landscape features, while Leisler's bat *N. leisleri* forage and commute across open habitats (Russ, 1999; Russ & Montgomery, 2002). The larger *N. leisleri* bat mostly uses relatively low frequencies giving a longer sonar range but a less detailed perception of small prey. The smaller *Pipistrellus* species use higher frequency echolocation calls giving shorter range perception with greater detail. They also fly more slowly than the Leisler's and are, therefore, less well equipped and less ready to cross large open areas (Limpens *et al.*, 1989; Russ, 1999).

In the Tannat Valley, Wales, the shortest route from a *Rhinolophus hipposideros* maternity roost to their foraging areas was frequently directly across fields. Despite this *Rhinolophus hipposideros* always followed linear landscape features (Schofield, 1996). Fences were not used. In the Tannat Valley study, a sensitivity to open space was evidenced by *Rhinolophus hipposideros* response to a 5m gap in hedgerow along a main commuting route. When crossing this gap *Rhinolophus hipposideros* was shown to fly below 1m at high light levels, but as light levels dropped, bats were recorded flying up to 4m above ground. Linear features appear to provide cover against predation by crepuscular (active at dusk) avian predators (Schofield, 1996). In the same study, at other breakages such as tracks or roadways (size not specified), *Rhinolophus hipposideros* were observed bridging these openings at points where canopies on either side on the gap touched.

Similar behaviour was observed at 2 of 4 *Rhinolophus hipposideros* study sites investigating commuting routes and foraging activity in Co. Clare (Biggane, 2004). At Kilmurray, *Rhinolophus hipposideros* was observed crossing the R462 road via overhanging mature tress which almost adjoin the hedgerow on the other side, showing a high dependence on tree canopy to bridge a regional road. At Tulla, *Rhinolophus hipposideros* was observed crossing a laneway and entering conifer plantation at the point where overhanging vegetation occurs on opposing sides of the road. The site at Kilmurray had hedgerow (route B) with a number of openings allowing cattle to roam between fields. Similarly, at Tulla, hedgerow (route D) is described as 'patchy and interspersed with fencing'. *Rhinolophus hipposideros* were still commuting along these routes.

A maternity roost in Kilkishen House had no immediate features (such as hedgerow) connecting the house to nearby mature trees. Here *Rhinolophus hipposideros* showed 'inventive' means of using different linear features along which to commute, using a nearby electric fence to the north and south of the house to reach outlying mature trees. To the south of the house, where the trees were far apart *Rhinolophus hipposideros* were observed flying close to the ground along the top of thistles *Cirsium* sp. (Biggane 2004).

Rhinolophus hipposideros have also been observed using stone walls and reedbeds to commute through their surroundings (Biggane 2003, cited in Biggane 2004).

Schofield (1996) states that *'the loss of the continuity of habitat may be as big a threat to the continued survival of this species as the loss of the habitat itself'* (Schofield, 1996:163).

Cryptic species have often been shown to have different habitat preferences (Davidson-Watts *et al.*, 2006; Russ & Montgomery, 2002). *Pipistrellus pipistrellus* is a more generalist forager, in terms of habitat selection, compared with *Pipistrellus pygmaeus* (Russ & Montgomery, 2002; Davidson-Watts *et al.*, 2006; Buckley *et al.*, 2007). Nicholls & Racey (2006) describe *'large and significant differences'* in the use of habitat by *Pipistrellus pipistrellus* and *Pipistrellus pygmaeus*. However, their study results are restricted to a single colony of each species.

2.1.1 Bat Echolocation and Survey

All Irish bats echolocate. In simple terms this involves the bat making a high pitched sound (usually at an ultrasonic frequency >20kHz) and using the echo that bounces off prey or obstacles to determine distance, based on the length of time taken for the echo to return. Echolocation is a highly evolved method of orientation and prey detection with which bats can build up an acoustic picture of their surrounding environment.

Bat detectors are used to listen to bat calls and convert echolocation sounds, which are usually beyond the range of human hearing, into an audible sound. One of the main advantages of using bat detectors is that they cause minimal disturbance to the bats, since they rely on the detection of echolocating bats while the bat is in flight (Fenton, 1997).

Some bat species are more detectable than others using bat detectors, depending on the loudness and frequency of their typical echolocation calls. Discrimination of *Myotis* species is problematic, particularly if the bat has not been seen in the field to evaluate its flight style. The lesser horseshoe bat, for example, can be difficult to detect in flight because of its very high frequency (approximately 110kHz) and directional echolocation calls which dissipate very quickly to the air. The brown long-eared bat is a quiet species and is, therefore, also difficult to detect (Russ, 1999).

There are several different kinds of bat detectors. Full spectrum bat detectors such as Time Expansion and Frequency Division bat detectors record a range of sound from the bat and are commonly used in surveys of bat activity. Recorded calls can be identified post survey using sonograms (i.e. pictorial representations of the call), and this may be among one of the most reliable methods of identifying bats in flight.

2.2 POTENTIAL EFFECTS OF ELECTRICITY TRANSMISSION INFRASTRUCTURE ON BATS

Transmission infrastructure includes overhead lines (OHL), underground cables (UGC) and substations. For the purposes of this study, OHLs are the main transmission infrastructure examined. Among the potential effects in the construction phase of transmission infrastructure on bat species are loss of roost sites (typically trees), and foraging and/or commuting habitat arising from clearance of vegetation to accommodate transmission infrastructure. With regard to operation of transmission infrastructure, potential impacts of EMFs, as well as the physical constraints that overhead lines and other infrastructure may have on bat activity are investigated.

2.2.1 Habitat Removal, Fragmentation and Disturbance

There is no international (published, peer reviewed) literature pertaining to infrastructure projects and their impacts on bats. A single national study (not peer reviewed) pertaining to transmission towers placed in hedgerows does occur (Tobin, 2011). To supplement this section, other habitat disturbance studies (notably forestry harvesting) are used to flag potential removal, fragmentation or disturbance issues. Forest clearance studies for example are a useful context as they can mimic clearance effects for transmission projects. The roost potential of individual trees for bats in terms of species, age and location is first discussed.

2.2.1.1 Tree Roosts

A construction project may require the removal of one or more live or dead mature trees occurring in hedgerow/linear features or woodland. Cavities in the trunk and branches of trees are widely used by vesper bats in temperate regions (Altringham, 2011). A roost is any place used by a bat for shelter or protection. Bats use trees as roosts because they provide a variety of conditions that bats require at different times of the year (Forestry Commission, 2005).

There has been no systematic study of Irish trees as bat roosts. In general, roost surveys have tended to focus on more easily accessible built structures which are simpler to survey. A review of Irish bat records from 2000-2009 is currently being carried out by Bat Conservation Ireland, and confirms that eight of the nine Irish species have been recorded roosting in trees, at least on occasion (N. Roche *pers.comm*.). The Nathusius' pipistrelle (*Pipistrellus nathusii*), a relatively rare species, is thus far the only species that has not been found using trees for roosting in Ireland.

There is no national published (peer reviewed) literature looking specifically at hedgerows as roosting habitat for Irish bats. Most of the international literature pertains to tree roosting bats in forests/ woodlands.

Andrews *et al.* (2013) present an account of tree roosting bats in the British Isles. The authors state that lesser horseshoe bat will roost in trees only in exceptional circumstances. However, it has been recorded in trees in Ireland on at least two instances in the past twenty years (N. Roche *pers.comm.*). In summer, the whiskered bat (and a cryptic *Myotis* species), Brandt's bat (*M. brandtii*) roost mostly in buildings and more rarely in trees (and not at all in winter) in Scandinavia, continental Europe and the UK (Harris & Yalden, 2008).

In Britain, Daubenton's bat is dependent on the presence of trees or woods for roosts (Vesey-Fitzgerald, 1949 cited in Andrews *et al.*, 2013) and rarely roosts far from water (Altringham, 2003). Trees favoured for roosting are oak, beech and ash (Harris & Yalden, 2008). In Ireland most Daubenton's roosts have been recorded from bridges (N. Roche *pers.comm.*).

In Northern Ireland, hibernacula of a number of radiotracked Leisler's bats were mainly recorded in mature deciduous trees, chiefly in splits in oak *Quercus* spp. and beech *Fagus sylvatica* (Hopkirk & Russ, 2004 cited in Harris & Yalden, 2008). In summer and winter brown long-eared *Plecotus auritus* will roost in trees (Harris & Yalden, 2008).

In Central Europe there is evidence of a benefit in retaining trees such as pedunculate oak *Quercus robur* and alder *Alnus glutinosa*. Pedunculate oak are longer lived and mature at a greater age whereas alder are short lived and mature at a younger age. Long and short lived trees together provide a continuity of cavities in which bats can roost (Lucan *et al.*, 2009).

Creating disturbance along a woodland edge might have implications for *Myotis daubentonii* (Boonman, 2000). In the Netherlands, Boonman (2000) found that *Myotis daubentonii* (and Noctule *Nyctalus noctula*) preferred to roost close to the edge of woodland, and may do so to reduce commuting flight costs or for thermoregulatory reasons. This is potentially an important consideration where the removal of woodland edge is needed for transmission line construction. However, with no systematic study of tree roosts undertaken it is hard to measure risk in such instances.

From available records and literature it is clear that almost all Irish bat species have used trees as roosts, at least on occasion. Removing older trees, be they individuals or part of a wider linear feature to accommodate high voltage electricity support structures, carries a risk that bat roosts may be lost as a result.

2.2.1.2 Loss of Commuting Features and Foraging Habitat

Entwistle *et al.* (2001) conclude that a gap of as little as 10m may deter a bat from its flight path. The lesser horseshoe bat (*Rhinolophus hipposideros*) in particular, avoids flying across open areas (Schofield, 1996). This is evidenced in its behavioural response to breakages in hedgerow continuity along commuting routes in Wales (Schofield, 1996) and Ireland (Biggane 2004).

In contrast Tobin (2011) found common and soprano pipistrelles actively foraging and crossing gaps in hedgerow where a pylon had been placed. Common pipistrelle was seen crossing a gap of ≥ 25m at three sites, including a 35m gap. Soprano pipistrelle was observed crossing a gap of ≥ 25m. At these particular sites, gaps were apparently void of any vegetation. Neither linear breakage nor steel lattice tower was a deterrent. At one site, Leisler's bat was seen actively foraging beneath transmission lines.

Hedgerows that are structurally complex and have a high diversity of vegetation are better for wildlife (Davies & Pullin, 2007). There is evidence to suggest the needs of bats, particularly foraging bats, can be more specific. Insect abundances will depend on the exact composition of the hedge in question (Sterry, 2007) i.e. some tree/shrub species support more insect than others.

Pedunculate oak also supports invertebrate life in abundance (Sterry, 2007); thus their occurrence in Irish hedgerows, treeline and woodlands may be particularly beneficial to bats. Brandt *et al.* (2007) found that one of their six hedgerow study sites that uniquely lacked pedunculate oak trees, had lower levels of recorded bat activity. Trees can act not just as wind breaks behind which insects can accumulate; they are an important habitat for invertebrates on which bats feed (Brandt *et al.*, 2007).

In south-western Ireland, Buckley *et al.* (2007) found that the edge of deciduous tree habitats, or habitats such as tree lines were most attractive to bats whereas coniferous tree plantations were not positively selected. The majority of forests in Ireland are even-aged commercial plantations of exotic conifers (Coote *et al.*, 2008).

Different styles of selective harvesting in addition to clear felling can create a mosaic of tree densities. This is likely to satisfy the needs of more bat species compared to a system with less diverse harvesting styles (Menzel *et al.*, 2002; Patriquin & Barclay, 2003). These authors are referring to studies in very large forest environments in North America with a different bat fauna. However, studies on open spaces in Irish plantation forests have already demonstrated enhancement potential (COFORD, 2004).

A study of short-term forestry disturbance in Canada (Grindal & Brigham, 1998) monitored bat (and insect) activity before and after harvesting three square sections of forest: 0.5, 1.0 and 1.5 ha. Bat activity increased in the summer after the squares were created. However, Grindal & Brigham (1998) stress the importance of remaining forest areas and their capacity to provide insect prey, roosting habitat and habitat used by interior forest-feeding bats.

Altringham (2011) states that forest/woodland cover is critical to many of the rarer bat species and this woodland should be mature and structurally diverse. While area reduction and fragmentation generally increases the amount of edge habitat, this may favour some species but reduce habitat quality for others (Altringham, 2011). For example, bats with a low aspect wing ratio (bats that typically forage in cluttered woodland habitats) tend to have small home ranges, small colonies, are specialist foragers and can have an increased extinction risk (Jones *et al.*, 2003; Safi & Kerth, 2004; cited in Altringham, 2011). There may be lessons here for woodland habitats in Ireland, despite Ireland's different bat fauna and considerably smaller, often fragmented woodlands.

2.2.1.3 General Disturbance

Noise and light resulting from construction machinery, equipment and activities may also impact on bat species. The clearance of vegetation to accommodate infrastructure requires the use of chainsaws, diggers, dumper trucks and/or wood chippers. If bedrock is encountered blasting may also be required. Construction activities and operations produce noise that may impact bat species. Traffic noise can deter species that forage by listening passively for prey (Schaub *et al.*, 2008 cited in Altringham 2011). However, Altringham notes that noise generated by vegetation movement could be equally or more disturbing (Altringham 2011).

Studies on the impacts of light on bats are more advanced than those on noise. Light sensitivity varies from species to species. The common pipistrelle for example is light tolerant while the lesser horseshoe is light sensitive (Altringham, 2011).

2.2.2 Electromagnetic Fields (EMF) and Fauna

An electric field is produced when voltage is applied through a conductor; the strength of the field depends on the level of voltage and the distance of exposure. The magnitude of an electric field is measured in volts per meter (V/m) or kilovolts per meter (kV/m). The strength of a magnetic field depends on the level of current and the distance of exposure. The magnetic flux density is expressed in tesla (T) or microtesla (μT).

In Ireland, electricity varies at a power frequency of 50 Hz (i.e. alternating back and forth 50 times per second) producing electric and magnetic fields. The electromagnetic fields emanating from OHLs are at the 'extremely low frequency' (ELF) end of the electromagnetic spectrum. Radio frequency (RF) is higher up the electromagnetic spectrum. Radio frequency is the rate of oscillation in the range of 3 - 300 GHz (Bat Conservation Trust, 2011).

No national or international (published, peer reviewed) literature on the effects of 'extremely low-frequency' (ELF) EMFs from OHLs was found pertaining to bats. However, studies on the effects of OHLs on other mammals (Ungulates) and birds (Aves) have been undertaken.

A review paper by Juutilainen (2005) reviews experimental studies on the developmental effects of EMF in animals. Most studies in mammals had shown no effects of prenatal exposure to ELF or Intermediate Frequency (IF) magnetic fields on gross external, visceral, or skeletal malformations. ELF electric fields up to 150kV were evaluated in several mammalian species showing consistent results suggesting no adverse developmental effects (Juutilainen, 2005). The author suggests additional studies on the subtle effects of developmental stability might increase understanding of biological organism sensitivity to weak low-frequency magnetic fields.

A mammalian study by Begall *et al.* (2008) investigates effects of ELF electromagnetic fields on magnetoreception. Faunal magnetoreception is a sense allowing a number of animals, including bats, an ability to perceive the Earth's magnetic field.

Studies on the effects of significantly higher forms of (non-ionising) electromagnetic radiation pertaining to bats do occur and are discussed in a separate subsection (2.2.2.3) on bats and EMF. Studies including the effects of radio frequency (RF) radiation on bats (Nicholls & Racey 2009), though inconclusive, are discussed.

2.2.2.1 Faunal Magnetoreception

A number of species including all major groups of vertebrates, as well as molluscs, crustaceans and insects show evidence for magnetoreception. Magnetoreception is a sense which allows the detection of magnetic fields in order to perceive direction, altitude or location. The evidence for magnetoreception is mainly behavioural with corresponding changes in species orientation or navigation (Lohmann, 2010). Grazing cattle, roe deer (*Caprelus capreolus*) and red deer (*Cervus elaphus*) were shown to naturally align their body axes in the geomagnetic North-South direction (Begall *et al.*, 2008 cited in Burda *et al.*, 2009).

The mechanism by which these species sense magnetic fields is not known for certain. One leading hypothesis is that crystals of the mineral magnetite (Fe_3O_4) provide the physical basis for magnetoreception. Magnetite has been detected in several magnetically sensitive species including salmon and rainbow trout (Lohmann, 2010). Magnetoreception is not confined to migratory species (Lohmann, 2010).

A study by Eder *et al.* (2012) looked closely at the functional behaviour of magnetic particles, *'most likely single domain magnetite'*, in the magnetoreceptor cells of trout. These inclusions were found to be firmly attached to the cell membrane, enabling a direct transduction of mechanical stress produced by magnetic force acting on the cellular dipole.

Other theoretical models assumed magnetite based magnetoreceptors as having a rotational motion i.e. not firmly attached to the cell membrane; freely rotating. Because there is no viscous damping, the magnetic inclusion or particle (attached to the cell membrane) becomes susceptible to extremely low frequency (50-60Hz) magnetic fields (ELFMFs). Eder *et al.* (2012) suggest that the magnetic field from overhead power lines may affect magnetic inclusions or particles that are firmly attached to the cell membrane citing a study by Burda *et al.* (2009) (discussed below) where overhead power lines were found to disrupt the magnetic alignment behaviour of ruminants.

There is limited evidence to suggest that the EMFs produced by OHL cause an obvious behavioural reaction in mammals. Burda *et al.* (2009) have shown that extremely low-frequency electromagnetic fields from high voltage electric power lines disrupt the natural or automated North-South body alignment of cattle and deer. This automated alignment with the earth's magnetic field (EMF) was evidenced in an earlier study by the same authors.

The 2009 study showed that cattle grazing under, or within the vicinity (<150m) of high-voltage power lines, did not exhibit the expected automated North-South alignment. They showed no preference for orienting their body axes in a certain direction. Similarly, roe deer in the vicinity (<50m) of high-voltage power lines showed a similar response with no preference for orienting their body axes in a certain direction. The effects, however, were shown to diminish with distance from power lines and these species began to realign their bodies along their natural or automated North-South axis.

Power line orientation or 'trending' also had an impact on alignment (examined in cattle only). This is due to the interaction of alternating magnetic fields (AMF) generated by the power lines and the earth's magnetic field. The alternating magnetic field (AMF) vector is horizontal and perpendicular to the conductors below the power lines. Therefore the angle between the AMF and EMF vectors and the resultant field characteristics depend on the direction of the power lines (Burda *et al.,* 2009).

2.2.2.2 Birds and EMF

A review by Fernie & Reynolds (2005) focused on research examining the effects of EMF from power lines on birds. Studies within their review examine a range of EMF intensities in both field and laboratory experiments. In summary, Fernie & Reynolds (2005) state that exposure *'generally changes'* behaviour, reproductive success, growth and development. However, there is a degree of uncertainty surrounding the findings on the effects of EMF exposure on birds due to the limited number of studies undertaken. Much of the research has found that EMF has generally affected birds (in some way) but the results are not always consistent in effect or direction.

Doherty & Grubb (1996) monitored breeding biology in three species using nest boxes placed beneath transmission lines: tree swallow *Iridoprocne bicolor*, eastern bluebird *Sialia sialis* and house wren *Troglodytes aedon*. Each species was assessed under each of three different transmission lines at three separate locations: one 765 kV transmission line and two 69 kV transmission lines. The sample of tree swallows associated with all three transmission lines exhibited lower reproductive success compared to control box. Eastern bluebird and house wren breeding success was unaffected (Doherty & Grubb, 1996). Control sites were chosen to match study sites in plant species composition, vegetation structure and proximity to water (Doherty & Grubb, 1996).

Nesting success was significantly higher for ferruginous hawks *Buteo regalis* nesting on a 500 kV transmission tower compared with ferruginous hawks nesting in natural sites. Nesting success for ravens *Corvus corax*, golden eagles *Aquila chrysaetos*, and red-tailed hawks *Buteo jamaicensis* was similar to their counterparts nesting on natural substrates (Steenhof *et al.*, 1993). This, therefore, shows a benefit for one species and no adverse impact on the others when nesting on transmission infrastructure. However, the authors cite differences between natural nesting sites and those on transmission towers. For example, nestlings on towers are more protected against range fires and mammalian predators than those at natural sites.

In one study, continued EMF exposure appeared to influence the growth of both male and female kestrel nestlings (Fernie & Bird, 2000). Nestlings exposed to EMF were heavier and had longer tarsai than control nestlings. However, other growth parameters were unaffected (Fernie & Bird, 2000).

Fernie & Bird (2001) examined if EMF exposure could elicit an avian immune response and alter oxidative stress levels. In one breeding season short term exposure resulted in a 'suite of responses' that included depressed total proteins, erythrocytes, lymphocytes, hematocrits, carotenoids and melatonin. However, 'no adverse health consequences were apparent' (Fernie & Bird 2001 cited in Fernie & Reynolds 2005).

The two studies by Fernie & Bird (2000; 2001) were conducted under aviary conditions (the previous studies looked at actual nest sites on pylons). The oxidative stress was measured in adult male kestrels, parents to the kestrel nestlings which showed the changes in growth. The electromagnetic field created in the lab was replicating that experienced by wild kestrels when nesting within 40m of a 735kV line running at peak capacity (Fernie & Bird, 2000).

Physiological effects of EMFs may be dependent on the 'type' of EMF exposure experienced, specifically whether the exposure is 'intermittent or continuous'. Adult birds are intermittently exposed to EMF from power lines on a daily basis, depending on the phase of the breeding season (Fernie & Reynolds, 2005).

The selection of studies discussed here demonstrates the inconsistencies 'in effect or direction' described by the authors. A great deal of uncertainty exists because of the limited number of bird studies on which to draw conclusive findings. They, for example, suggest that further research is needed to determine whether EMF exposure alters the multifaceted endocrine and immune systems of birds. A similar recommendation is made by Juutilainen (in 2005) for further studies on the more 'subtle' effects of low frequency magnetic fields.

2.2.2.3 Bats and EMF

Bats have been shown to use magnetoreception for directional orientation and navigation (Holland *et al.*, 2006; Wang *et al.*, 2007 & Holland *et al.*, 2008). The big brown bat *Eptesicus fuscus* has been shown to possess a magnetic compass for homing (Holland *et al*., 2006).

By presenting a magnetic field that masks the earth's natural one, it is possible to exert a disruptive influence. Holland *et al.* (2006) used a Helmholtz coil to alter the magnetic field of captured big brown bats *Eptesicus fuscus* and released them 20km north of their roost. Some of the 'deflected' bats corrected and returned home to their roost that night. They recognized a mismatch between the direction they were flying and their navigational map i.e. using the earth's magnetic field. Orientation was significantly southerly in control bats that were not subject to an altered magnetic field.

Wang *et al.* (2007) also altered the magnetic field around captured Chinese *Nyctalus plancyi* bats and found changes in orientation, though on this occasion in the confines of a laboratory. Their results show that bats respond to 'polarity' not 'inclination', i.e. using the polarity of the magnetic North and South as opposed to 'inclination' which instead relies on the axial course of the field lines (Solov'yov & Greiner, 2009).

Holland *et al.* (2008) found that the big brown bat *Eptesicus fuscus* uses magnetite to detect the earth's magnetic field. They hypothesised that sensory cells in bats contain freely rotating magnetite particles.

Recent findings by Eder *et al.* (2012) for trout are contrary to the theoretical model proposed by Holland *et al.* (2008) i.e. sensory cells in bats contain freely rotating magnetite. If the sensory cells in bats contain freely rotating magnetite, based on Elder *et al.* (2012) findings, bat magnetoreception may not be susceptible to extremely low frequency electromagnetic fields . OHL may not then have a disruptive influence on bat magnetoreception.

In the review paper '*non-ionizing radiation (NIR*) *and wildlife,* Cummins & Osborn (2002) did not cite any studies on bats. However, they made a specific recommendation to measure NIR behind/around wall-mounted antennas, particularly in the vicinity of bat roosts. It is important to state that radio frequency (RF) is used to operate such telecommunication systems. This frequency is further up the Electromagnetic Spectrum and significantly higher frequency than that of OHL (see Figure 1.4).

In Valladolid, Spain, Balmori (2003) found the number of bats in a colony of free-tailed bat *Tadarida teniotis* decreased when several phone masts were placed 80m from the colony. The number of common pipistrelles also decreased in 'some areas' (unspecified by the author) (Balmori, 2003). However, Balmori (2003) does not state if this decrease is with reference to roosts or foraging activity. In a review study on electromagnetic pollution from phone masts, Balmori (2009) states that pulsed telephony microwave radiation can produce effects. Again, these radio frequency telecommunications systems are much higher frequency than that of OHLs.

Nicholls & Racey (2007) studied the effects of radio frequency radiation associated with radar installations on bat activity. An aversive behavioural response was observed. Thermal induction (resulting from EMF exposure) may provide an inhospitable thermal regime for foraging bats, which could vary from discomfort to hyperthermia depending on EMF strength and duration of exposure (Nicholls & Racey 2007). Bat activity was significantly reduced in habitats exposed to an electromagnetic field greater than 2 v/m in habitats <200m from the radar installation compared to (control) EMF levels measuring zero in control habitats (Nicholls & Racey, 2007).

Nicholls & Racey (2009) also hypothesised that bats can effectively 'hear' the pulsed microwaves produced by a portable radar installation (based on results from laboratory experiments; radar essentially produces an audible sound wave in the head), and that the frequency heard lies within the range used for bat orientation, prey detection and capture.

Nicholls & Racey (2009) showed that an electromagnetic signal from a small radar unit with a fixed 'unidirectional signal' invariably reduced bat activity within 30m of the unit. However, insect abundances (which were simultaneously measured) showed no significant sensitivity. There was no significant fall in activity when the radar was rotating. With a rotating beam bats were only momentarily exposed to pulse-modulated microwave radiation. Although bat activity was significantly reduced during experimental trials, substantial numbers continued to forage within the beam. A particular combination of wavelength, pulse repetition rate, power output and target size and orientation may provoke a reaction (Nicholls & Racey, 2009). These studies must be placed in the context of exposure to significantly higher levels of EMF than that which would occur around OHLs.

2.2.3 Collision and Electrocution

In this section the physical presence of OHLs and potential impacts on bats is explored.

There is no national or international (published, peer reviewed) literature on bat fatalities from power line collision. Orbach & Fenton (2010) cite only *'anecdotal reports'* of bats colliding with other stationary objects including television towers. One bird study in California did however report a single (unidentified) bat found during a search for bird carcasses surrounding a 110 kV transmission line (Dedon *et al.*, 1989).

Visual capabilities of insectivorous bats vary considerably, from species with modest acuity to those with high acuity. Light intensities may influence collision as well as behavioural, hormonal and physiological changes during swarming and mating (Orbach & Fenton, 2010).

The only published information on bat collisions with manmade structures pertains to wind turbines. Bat fatalities in North America and Europe have led to growing concern about the siting and operation of wind turbines (Bat Conservation Trust, 2009). For example, during a six-week period in 2004, an estimated 1,764 and 2,900 bat fatalities were recorded at two wind farms in West Virginia and Pennsylvania (Arnett, 2005 cited in Nicholls & Racey, 2009). However, only the moving part of these structures has been implicated in bat fatalities. Random collisions; temporarily switching off their echolocation capabilities, and vortices created by moving blade, have all been linked to fatalities (Bat Conservation Trust, 2009).

Some species found overseas have exceptional avoidance capabilities. The little brown bat *Myotis lucifugus* can almost perfectly avoid vertical wires of only 0.3 mm diameter when flying at between 3 and 4.4 m/s (Griffin, 1958:357 cited in Lee *et al.*, 1992) while the trident bat *Asellia tridens* can reliably negotiate wires as thin as 0.065 mm (Gustafson & Schnitzler 1979 cited in Lee *et al.*, 1992). Neither species are resident in Ireland but four different *Myotis* spp. do occur.

There is no national (published, peer reviewed) literature on bat fatalities from power line electrocution. Avian electrocution occurs when a bird is able to bridge any two energized conductors (Janss, 2000). International (published, peer reviewed) literature only reveals regular fatalities of grey-headed flying-fox *Pteropus poliocephalus* endemic to Australia. This very large fruit bat (with a wingspan up to 1m) is able to bridge energised conductors with its wings (VGDSE, 2011). The shortest phase to phase conductor spacing in Ireland for 110 kV in the field is generally 4.5m (EirGrid, 2012). Leisler's bat, the largest species in Ireland, has a wingspan of just 26-34 cm (Altringham, 2003) thus making electrocution impossible.

2.2.4 Bat Activity and Survey Methodology

There is abundant literature comparing levels of bat activity in different habitats or under different environmental conditions. Examples include some of the papers cited in the present introduction – such as Russ & Montgomery (2002); Nicholls & Racey (2009); Boughey *et al. (*2012), etc. All of these studies have been bat detector-based, relying on measured numbers of bat passes (i.e. a sequence of bat echolocation calls as bat travels within range of a bat detector), but have used a variety of methods such as driven transects with subsequent analysis of bat sounds (e.g. Russ & Montgomery 2002), walked surveys with surveyors identifying and counting bats on the spot (e.g. Boughey *et al.* 2012), or detecting bat activity in the field using stationary remote detectors (Nicholls & Racey 2009).

For any bat activity study, results can be highly variable depending on many factors such as time of year, time since sunset, weather conditions, distance from roost, and insect availability. Thus, bat monitoring schemes and bat activity surveys depend upon multiple sampling and robust statistical analyses in order to ascertain whether conclusions can be made about bats' preferences for, or avoidance of, particular conditions.

On the basis of bat activity surveys and subsequent data analysis, it may be possible to determine whether there is a difference in bat occurrence close to or at a distance from OHLs and support structures. Certain conditions such as differing habitats can be accounted for in the statistical analysis process. However, if bats are found to be less likely to occur at or near OHLs it will not be possible to determine, on the basis of a bat activity study, if OHLs negatively impact on bats by interfering with magnetoreception, by causing physiological or other stresses, or due to some indirect effect such as decreased insect availability. Reasons other than the presence of OHL may explain low activity.

3 BAT SURVEY METHODOLOGY

3.1 OVERALL APPROACH

To assess whether the presence and operation of high voltage overhead transmission lines impact on bat activity, surveys were undertaken. Initially, a GIS dataset by Lundy *et al.* (2011) identifying the broad scale geographical occurrence of each bat species in Ireland was reviewed. The associations that caused these patterns were used as a starting point to inform the site selection for this study. The Lundy study identified 'Core Favorable Areas' for individual species and for 'all' species. In this instance the GIS dataset combining 'Core Favorable Areas' for 'all' species was used.

In Ireland, most existing transmission lines are located within the agricultural landscape. This is primarily due to the fact that this is the most common land use in Ireland. As a benefit however, agricultural lands are invariably more accessible, which is desirable for transmission infrastructure construction and maintenance. Furthermore, these lands too are typically improved grasslands of low biodiversity value.

In order to investigate these 'Typical Conditions', CORINE (2006) Land Cover (CLC), Class 2 Agricultural Areas were used to identify the following land cover classes: 231 Pasture, 241 Arable, 242 Complex Cultivation Patterns, 243 Land principally occupied by agriculture with areas of natural vegetation. OHLs were identified of each voltage (400 kV, 220 kV and 110 kV) within CLC Class 2 Agricultural Areas.

To help determine whether the presence and operation of high voltage overhead transmission lines impact on bat activity, the following sub-questions were addressed:

- Are bats active in the vicinity of overhead lines?
- Does the placement of towers in or beside hedgerows and associated hedgerow maintenance (cutting), prevent bat activity along these linear features?

To test if bats actively avoid overhead lines, bat presence or absence was examined along a gradient by means of a **Driven Transect Survey** method.

To test if bats actively avoid towers placed in or beside hedgerows or recently cut hedgerows, bat species presence or absence was examined by means of a **Passive Monitoring Survey** method.

The Lundy *et al.* (2011) study and the CORINE Land Cover data informed site selection for both surveys. The driven transect survey design was informed by a Berthinussen & Altringham (2012) study where acoustic surveys were carried out on walked transects approximately perpendicular to a major road in Cumbria, UK.

3.2 DRIVEN TRANSECT SURVEY

3.2.1 Site Selection

In order to investigate if bat activity is influenced by the presence of OHLs, it was important to locate study areas where bats would be expected and where OHLs were surrounded by suitable foraging habitat. This counteracts the possibility that the absence of bats around OHLs is simply an artifact of the exposed location of the OHL. Therefore, sites were selected where the OHL crossed a road with adjacent hedgerows.

The following CLC classes were avoided by 1km where possible as these habitats are particularly synonymous with elevated bat activity: Class 1 Artificial Areas, Class 3 Forest and Semi-Natural Areas, Class 4 Wetlands and Class 5 Waterbodies. Transects in close proximity to such habitats could yield a biased data set at survey stops along that transect.

Where possible, survey sites were selected on third class roads and or laneways within 'Core Favourable Areas' running perpendicular or close to perpendicular to OHLs (400 kV, 220 kV & 110 kV). Aerial photography was used to aid site selection (© Google Earth).

3.2.2 Survey Method

The starting point of each transect was directly beneath the centre overhead line (Point 0). The survey vehicle was driven at 10mph (16kmph) between sample points. Each sample point was surveyed for 10 minutes while the vehicle was stationary at 0, 25, 50, 100, 200 and 500m using an AnaBat SD2 Compact Flash Bat Detector (Titley Scientific). The microphone was mounted on the car roof pointing upwards (see Figures 3.1 & 3.2). Bat activity was recorded onto a 2 GB internal memory card (Flash Card). Distance from Point 0 was measured using a 'Garmin eTrex H' handheld GPS device. Transects were completed in favourable weather conditions, avoiding wet, windy or cold nights. Windiness, precipitation, temperature and cloud cover were recorded at Point 0.

Although transects were selected for their habitat homogeneity, some variation of habitat was still present and therefore habitats were recorded and classified into five categories (see Table 3.1), in order to account for this variability in the statistical process. Each transect commenced no earlier than 30 minutes after sunset (see Table 3.2). Up to three surveys were carried out on a single night. A sample data recording sheet can be found in Appendix B.

Table 3.1: Habitat Categories

Grade	Habitat
1	Fence or wall lining road and open fields beyond.
2	Hedges/shrubby verges lining road and open fields beyond.
3	Intermittent medium trees/bushes lining road and open fields beyond.
4	Intermittent tall trees lining road and open fields beyond.
5	Continuous tree cover lining road with woodland and/or open fields beyond.

Table 3.2: Driven Transect Survey Start Times

17 sites were surveyed from 30 minutes after sunset
4 sites were surveyed from >30 minutes and <1hr after sunset
23 sites were surveyed from >1hr after sunset

A total of 45 sites were selected across Ireland (see Figure 3.3) (See Appendix B1 – B3 for Driven Transect Survey Data Sheets). Sites surrounded by habitat with a high degree of homogeneity were selected. Statistical analysis to account for habitat and other differences was used. Each of the six stops was scored for bat presence or absence.

3.2.3 Statistical Analysis

The driven transect study was designed to be similar to the work described in the paper by Berthinussen & Altringham (2012), which was analysed by log-transforming the counts and then fitting a model using Generalised Estimating Equations (GEE) with an autoregressive correlation structure. In the current work only bat presence/absence was recorded, and so a binomial GEE was initially fitted with the same correlation structure. However, these models did not converge successfully and closer examination showed that there was no sign of any spatial correlation; i.e. adjacent observations showed no sign of being more similar than those further apart.

In view of this, a mixed logistic regression model was used, using the HGLM (Hierarchical Generalized Linear Model) approach (Lee & Nelder, 2001). This allows for the fact that observations at one site will be more similar than those at different sites, but does not allow for any spatial correlation within sites. It produces significance tests for the explanatory variables and estimated mean percentages, adjusting for any confounding variables (e.g. habitat types) fitted in the model.

The statistical software Genstat was used for statistical analysis.

3.2.3.1 Limitations of Driven Transect Survey

One of the 45 sites was not surveyed (on the 400 kV line) due to time constraints, primarily caused by exceptionally bad weather throughout the 2012 survey season.

Figure 3.1: Driven Transect Site Example[11]

Figure 3.2: Survey vehicle with Anabat microphone mounted on car roof

[11] *(Site 10L201 Tallanstown, Co. Louth. Survey Point: 0 Meters - directly beneath the overhead line. Habitat type: 2 – 'Hedges/shrubby verges lining road and open fields beyond'. AnaBat SD2 microphone mounted on the car roof. This site was surveyed officially on the 19/07/2012.)*

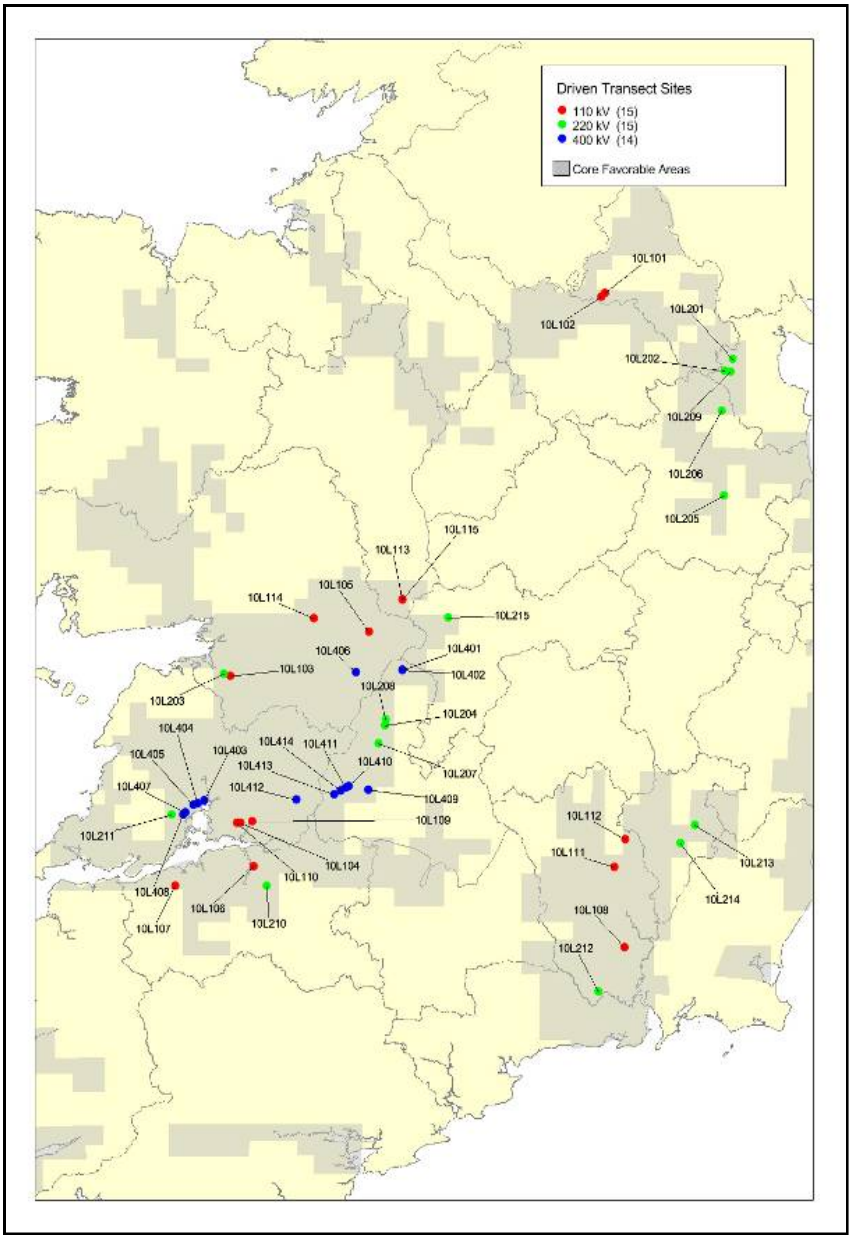


Figure 3.3: Location of Driven Transect Sites (on background map from Lundy *et al.* (2011))

3.3 PASSIVE MONITORING SURVEY

3.3.1 Site Selection

Sites were selected where steel lattice towers straddled, or were situated immediately adjacent to a hedgerow (i.e. a maximum distance of 5m). A total of 45 sites were selected with 15 of each line type: 400 kV, 220 kV and 110 kV. Multiple sites were selected using aerial imagery to isolate towers occurring in or beside hedgerow. Their suitability for survey was confirmed through site visits. To assess the impact of hedgerow cutting beneath towers on a maintenance cycle, even numbers of ‘managed’ and ‘unmanaged’ hedgerows were selected. These are defined as follows:

Managed: common small tree species such as hawthorn *Crataegus monogyna*, blackthorn *Prunus spinosa* and elder *Sambucus nigra* are subject to periodic cutting giving a well-defined or general box shape appearance. Individual unmanaged large trees such as ash *Fraxinus excelsior* are absent or intermittent.

Unmanaged: species such as hawthorn, blackthorn and elder have grown unchecked. Larger tree species are distinguished by their open crown canopy extending beyond the frequent hawthorn or blackthorn component.

3.3.2 Survey Method

Four of the 45 selected sites were not surveyed due to access and site suitability issues: one each on the 220 and 400 kV towers and two on the 110 kV towers. As such, between June and September 2012, automated passive monitoring was undertaken at 41 sites selected across Ireland (see Table 3.3 and Figures 3.4 & 3.5).

At each site an AnaBat SD2 Compact Flash Bat Detector (Titley Scientific) powered by a 12V external battery was housed in a purpose built box, constructed to look like a bird nesting box. This ensured adequate weatherproofing as well as deflecting unwanted attention (see Figures 3.6a & b). The box was fixed to the pylon structure approximately 2m above ground. The bat detector was programmed to automatically start operating at 30 minutes before sunset until 30 minutes after sunrise at each deployment, thus ensuring all the very earliest and latest activity is captured. The bat detector was left in position to record for a period of one week on each occasion. AnalookW Version 1.1 was used to undertake analysis of data collected during automated passive monitoring.

Leisler’s bat, brown long-eared bat and lesser horseshoe bat were identified to species level. Pipistrelle bats (common pipistrelle and soprano pipistrelle) were pooled into the group – *Pipistrelle* spp. Whiskered bat, Daubenton’s bat and Natterer’s bat are the most difficult species to distinguish and were collectively categorized as *Myotis* spp. (Russ, 1999). Individuals and groups were scored for presence or absence at each site. (See Appendix C4 - C25 for individual passive monitoring site photographs).

Table 3.3: Numbers of Managed and Unmanaged Hedgerow Passive Monitoring Sites.

	Managed	Unmanaged
100 kV	6	7
220 kV	7	7
400 kV	7	7

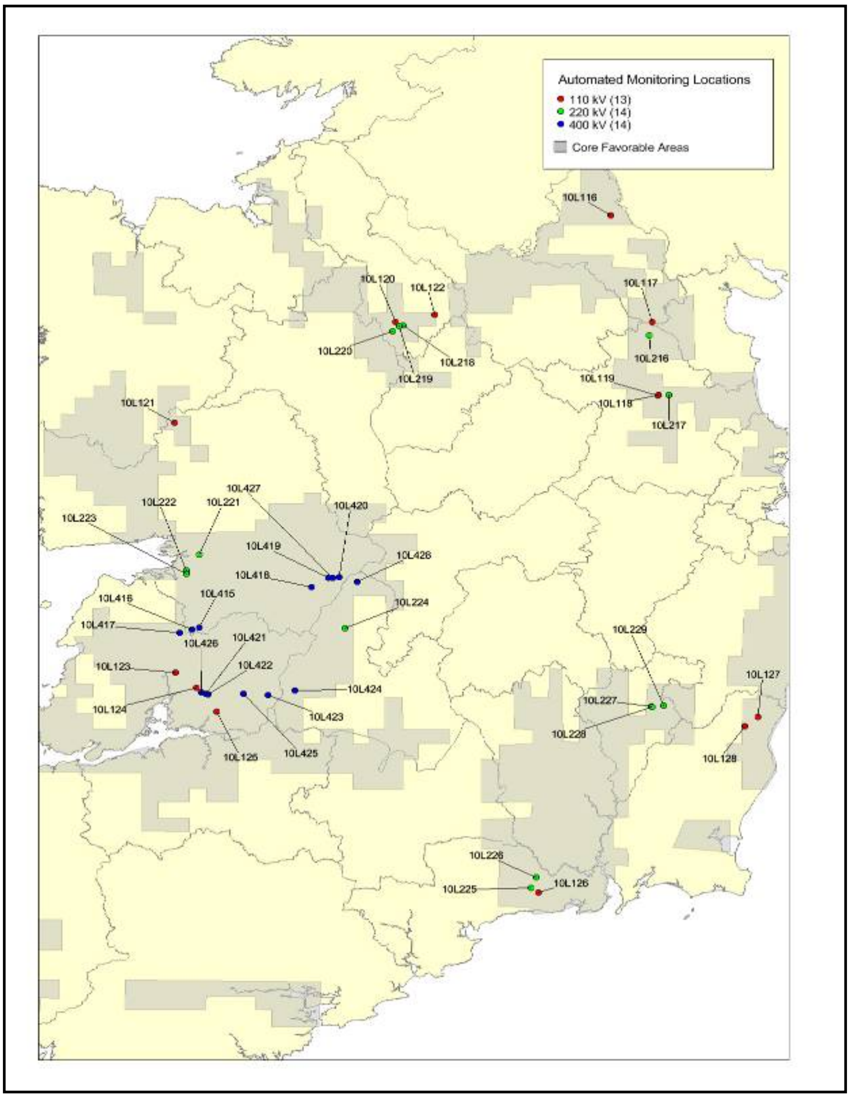


Figure 3.4: Location of Automated Passive Monitoring Sites, 2012 (on background map from Lundy *et al.* (2011))

Figure 3.5: An example of a Passive Monitoring Site (Site 10L228 Drisoge, Co. Wexford. A 'Managed' Hedgerow Site. The entire hedgerow has been cut by the landowner, in this instance in Sept. 2012).

Figure 3.6a: The purpose built 'mock' bird nesting box with the AnaBat SD2 microphone positioned at the front opening.

Figure 3.6b: Bird box (with bat detector within) attached to the tower

3.3.2.1 Limitations of Passive Monitoring Survey

As noted above, four of the 45 selected sites were not surveyed due to access and site suitability issues. Despite these constraints, surveys were carried out across a wide geographic range within the ‘Core Favourable Areas’ for all bat species.

Furthermore, it was initially hoped to select sections of field boundaries that had been trimmed in 2011 and deploy bat surveying equipment in the centre of that trimmed area. Control sites would then be placed in the next closest field boundary or a point on the same linear feature 25m distance from the trimmed zone.

However, there were insufficient records on hedgerow maintenance available to apply this methodology. The above question was addressed as far as possible, within the limits of available information, by comparing ‘unmanaged’ hedgerows, i.e. those that do not appear to ever have been cut by the landowner with ‘managed’ hedgerows; those where management is obviously occurring. This applies to the entire hedgerow / field boundary either side of the tower.

3.4 OVERALL SURVEY

The regional distribution of both driven and automated passive of study sites are shown in Table 3.4.

Table 3.4: Total Number of Driven and Passive Monitoring Sites: Regional Distribution

Region	Driven Transect Sites	Automated Passive Monitoring Sites	Total No. of Sites
Sector 1 - The Border and West Regions	7	11	18
Sector 2 - The Midlands, Mid East, South East and Greater Dublin Regions	21	15	36
Sector 3 - The Mid-West and South West Regions	16	15	31
Total no. of Sites	**44**	**41**	**85**

4 RESULTS

4.1 QUESTION 1: *DOES THE SCIENTIFIC LITERATURE PROVIDE EVIDENCE THAT THE PRESENCE OF OVERHEAD TRANSMISSION LINES, INCLUDING ASSOCIATED ELECTROMAGNETIC FIELDS, HAVE AN EFFECT ON BATS?*

4.1.1 Use of the Landscape by Bats

The literature review identified both subtle and significant differences in hedgerow dependence between species. Where hedgerow is removed to accommodate towers, these breakages in connectivity could adversely affect foraging and commuting bats (Entwistle *et al.*, 2001). Lesser horseshoe bat *Rhinolophus hipposideros* have been shown to be entirely dependent upon a continuity of linear features to access main foraging areas and show clear behavioural responses to breakages in these routes. This is shown for example in their use of overhanging canopy to bridge roads and laneways. Abiotic linear features such as stone walls, and in one survey location, electric fences have also been utilised (Biggane, 2004).

Most of the peer reviewed studies relating to bats and linear feature relationships were based in the UK and Europe. Hedgerow structure and species composition in Ireland will differ from other countries. Average field size will be much reduced here compared with that of England for example. Hedgerow structure, the frequency and species of trees present and proximity to roosts are among the key variables that determine the levels of association between linear features and individual bat species. Specialist foragers, generally, are more affected by fragmentation (Altringham, 2011).

4.1.2 Habitat Removal, Fragmentation and Disturbance

4.1.2.1 Construction Phase

There is potential for the construction of high voltage overhead transmission lines to impact on bats in a number of ways. By reducing habitat availability or increasing edge effects in wooded habitats, bat foraging areas may be increased or reduced, depending on a species' morphology and echolocation capabilities. Generalist species may benefit, while specialist woodland species may be negatively impacted. Allowing the regeneration of scrub vegetation under a newly constructed power line could benefit a range of bat species following line commissioning, and help offset habitat loss.

With the exception of one national study pertaining to hedgerows (not peer reviewed), no other national or international studies occur assessing the impacts of high voltage overhead transmission line infrastructure on bat activity post construction. In the single national study, variable levels of permanent hedgerow loss were observed at some 220 kV and 400kV located in hedgerows at existing transmission tower locations (Tobin, 2011).

In the absence of construction related literature, more general assertions are made based on other disturbance activities studies such as forestry activities. In a single Irish study, conifer plantation edge was not positively selected by bats. Tree felling in plantation forest can create more forest edge, thus increasing available foraging habitat for general species that can adapt quickly to change. Where clearance occurs in more structurally diverse forests, emphasis should be on retaining as far as possible these diverse areas.

In Ireland, a Site Evaluation Scheme adopted by the NRA, and more recently EirGrid, has a capacity to identify mixed habitat types that form a discrete area of ecological value.

The erection of high voltage electricity support structures may necessitate the removal of trees. No national published peer reviewed literature specifically examines hedgerows as roosting habitat for Irish bats. However, eight of the nine Irish bats have been recorded roosting in trees, at least on occasion; thus clearing trees that have roost potential may pose a risk to bats.

In Ireland, Nathusius' pipistrelle is thus far the only species not to have been found using trees for roosting. The literature highlights the importance of tree age, species and location when determining the bat roost potential. In Northern Ireland for example, Leisler's bat have been recorded in mature oak and beech trees.

On occasion, transmission line projects also traverse forests. The Life Elia Project is an initiative to improve forest corridors created by high-voltage lines. (ELIA manage the Belgian high voltage network. The project also includes RTE who manage the French electricity transport network).The Life Elia Projects in Belgium and France has shown that areas of clearance can be enhanced by planting tree and shrub species of local provenance along the forest edge. This project demonstrates that areas of clearance can be enhanced to provide a wildlife benefit (including bats) and at the same time not posing any risk to the infrastructure.

Creating edge structure is a similar objective in South East Queensland Australia linking with retained bushland nearby, being undertaken by a not-for-profit conservation organisation - SEQ Catchments - and electricity transmission company Energex. Similar to the Life Elia Project, the structure of the edge and the distribution of species was made on basis of their height at maturity; thus larger trees will not impinge on infrastructure in the future (SEQ Catchments, 2012). In this instance, transmission lines were on occasion passing through important ecological corridors including important koala *Phascolarctos cinereus* habitat.

4.1.3 Operation of high voltage electricity infrastructure

Despite a comprehensive literature search, no national or international peer reviewed published studies occur pertaining to impacts of OHL derived electromagnetic fields on bats. The limited research available for other faunal groups and OHL is somewhat contradictory in nature. For birds, negative or potentially negative effects on reproductive success or immune responses have been observed for some species in the wild and in laboratory settings, whilst no effects or positive impacts have been observed for other faunal groups.

A number of species including all major groups of vertebrates, as well as molluscs, crustaceans and insects show evidence for magnetoreception, including bats. Research into the mechanisms by which animals sense the Earth's natural magnetic field is ongoing.

Studies of bat activity in the vicinity of radar transmitters have shown a negative association, with bats less likely to occur. However, radar produces an EMF that is higher on the electromagnetic spectrum so it is not comparable with EMF produced by the electricity transmission network. In one study bats have been found to avoid roosting near mobile telephone masts. Again however, the EMF produced by such structures differ substantially from those emanating from OHLs.

Due to the lack of published evidence on the potential impacts of EMF generated from OHLs, and the limited and conflicting evidence emanating from studies of other species of fauna, it is not possible to determine definitively if EMF has any impact at all on bat species. This literature review concludes that a correlation has not been identified between EMF emanating from OHLs and any negative association with bats.

4.1.3.1 Collision and Electrocution

There is just one reference (Dedon *et al.,* 2012) in the published literature to a bat corpse found under a power line and this a study based on bird collisions in the US. The only published information on bat collisions with manmade structures pertains to wind turbines. Based on this current study, collision with power lines is considered to be a very low risk for most Irish bat species, since their echolocation capabilities should allow them to detect support structures and lines.

Electrocution caused by interaction with electricity transmission infrastructure is not possible for the Irish bat fauna. Conductor spacing at 110 kV line for example is a minimum of 1.1m, and is generally 4.5m in the field. The largest Irish bat has a maximum wingspan of only 34cm.

4.2 QUESTION 2: *DOES THE PRESENCE AND OPERATION OF HIGH VOLTAGE OVERHEAD TRANSMISSION LINES IMPACT ON BAT ACTIVITY IN THE NATURAL ENVIRONMENT?*

4.2.1 Driven Transect Survey

4.2.1.1 Results of Statistical Analysis

Results are presented as the percentage of 10 minute survey periods in which bats were present. These percentages were based on the results of the logistic regression model in order to adjust for the effects of habitat and to allow the calculations of standard errors. Figure 4.1 shows the percentage of 10 minute survey periods with bats, for each combination of line voltage and distance. They differ slightly from the simple mean ('mean % with bats') because they are adjusted as if all combinations of line voltage and distance had the same habitat.

The error bars represent one standard error; there is a 68% chance that the true mean is within one standard error of the value shown, or a 95% chance that the true mean is within two standard errors (i.e. twice the width of the bars show). It is therefore likely that much of the variation between the bars is due to random variation.

Weather variables were not included in the model as they did not show a statistically significant effect on bat presence or absence (wind χ^2 = 1.00 with 2 d.f., *P*=0.606, cloud χ^2 = 0.06 with 2 d.f., *P*=0.969, rain χ^2 = 2.64 with 2 d.f., *P*=0.105).

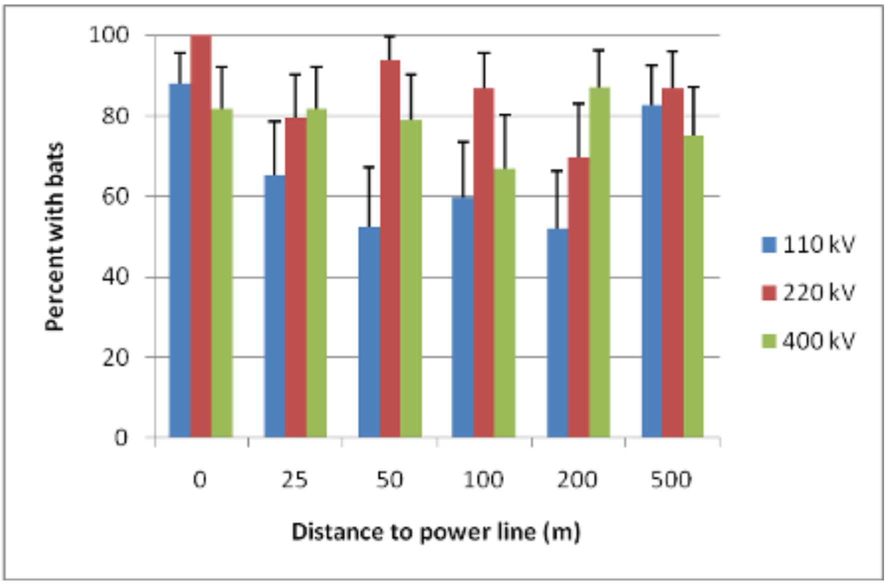


Figure 4.1: Percentage of survey points where bats were recorded in relation to distance from powerlines of various voltages (habitat variable controlled in the logistic regression).

Estimated means from a model with terms for line type, distance and their interaction, plus habitat. Means are adjusted for the effects of other factors in the model. Bars represent one standard error.

Bats were present at all distances for each line voltage. On the 400 kV line, bats were consistently present at all distances (between 66.8 and 87% of sites). 81.9% of the 400 kV sites beneath the line (at zero distance) had bats present. On the 200 kV line, 100% of sites beneath the line had bats present. The 110 kV line had the highest percentage of sites, with bats (88.1%) beneath the line. Conversely, the lowest percentage of sites with bats (on the 110 kV line) was at 200m.

Little relationship is apparent between bat presence and distance from the power line, although there is a slight tendency for bats to be more frequently present immediately under the power line. These results are based on a model with an interaction between distance and line voltage (i.e. allowing the effect of distance to vary between line types), but this term (i.e. interaction between distance and line voltage) is not statistically significant (χ^2 = 9.21 with 10 d.f., *P*=0.512), suggesting that a model without this term is adequate.

Figure 4.2 shows the relationship for distance, line type and habitat separately, adjusted to remove the effects of the other factors. Also shown in the caption to Figure 4.2 are test statistics for the three factors in the model.

Line type is the closest to the usual *P*=0.050 value used to indicate significance, with 110 kV lines showing a lower likelihood of bat presence than other, higher voltage lines. Since the finding is not quite significant and is somewhat implausible, this is thought to have been a chance effect.

Distance is not significant with, if anything, a trend for more bats close to the power line.

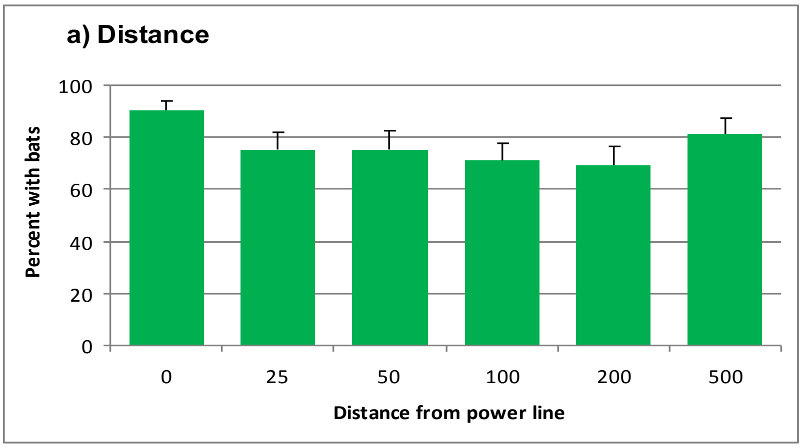
Habitat is also not significant, but the trend (i.e. greater likelihood of bats being present in wooded setting, such as group 5) is plausible. The lack of significance may be partly due to the low sample size for most groups.

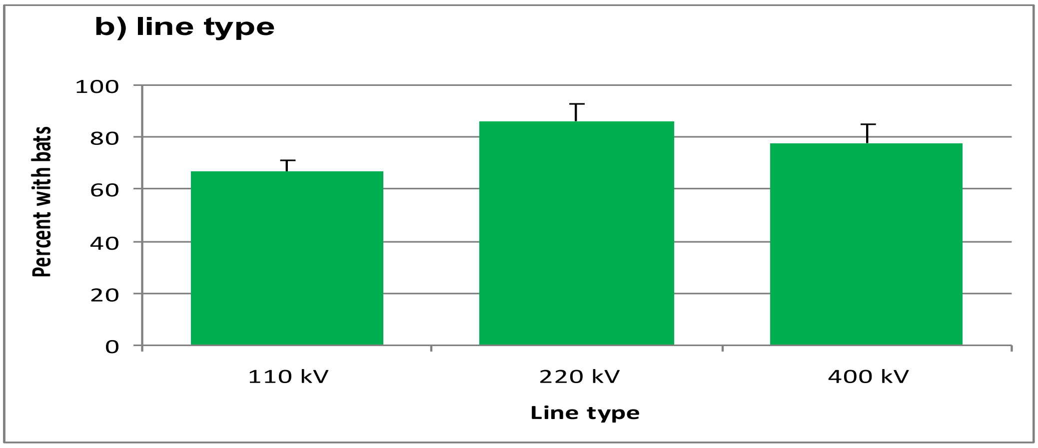
Over half of the survey points were Category 2 (see Table 3.1 above for habitat categories).

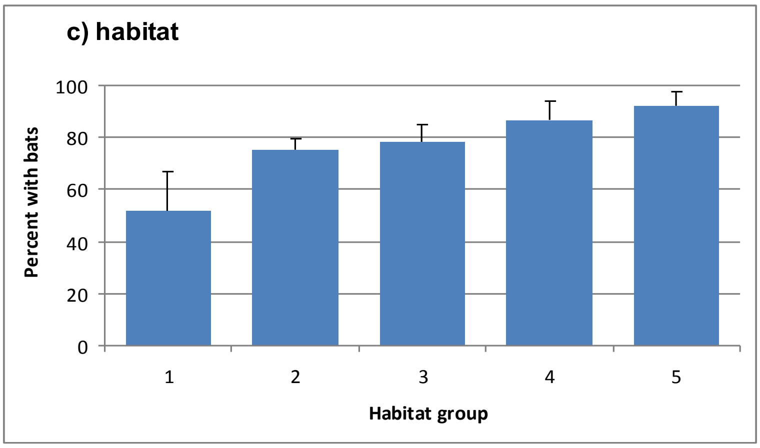
Figure 4.2: Estimated Means from a Model Allowing for the Effects of Line Type, Distance and Habitat Group.

Means are adjusted for the effects of other factors in the model. Bars represent one standard error.

Term	χ2	d.f.	P.
Distance	8.133	5	0.149
Line type	5.235	2	0.073
Habitat Group	7.049	4	0.133







Although no discrimination was made between bat species for overall analysis, on two instances, common pipistrelle bat was observed foraging up and down the road at Point 0, beneath the overhead lines (site 10L205 Tara, Co. Meath; site 10L213 Sragh, Co. Carlow).

There was no significant difference in bat activity recorded immediately under high voltage lines (where EMF levels are highest) when compared with bat activity at increased distances from OHL (where EMF levels are significantly reduced).

4.2.2 Passive Monitoring Survey

4.2.2.1 Results of Statistical Analysis

For passive monitoring, presence / absence data (by species) was recorded during the survey period. Graphs of mean percentage of sites with each species and standard errors were produced for the three factors of interest: (a) line type, (b) hedgerow management and (c) whether within 1km of a lesser horseshoe (LHS) roost (Fig. 4.3). 10 of the 41 sites occur within 1 km of a LHS roost, based on known roost locations provided by NPWS. As LHS bat is an Annex II species it was decided to statistically investigate its occurrence at towers (Fig. 4.3c).

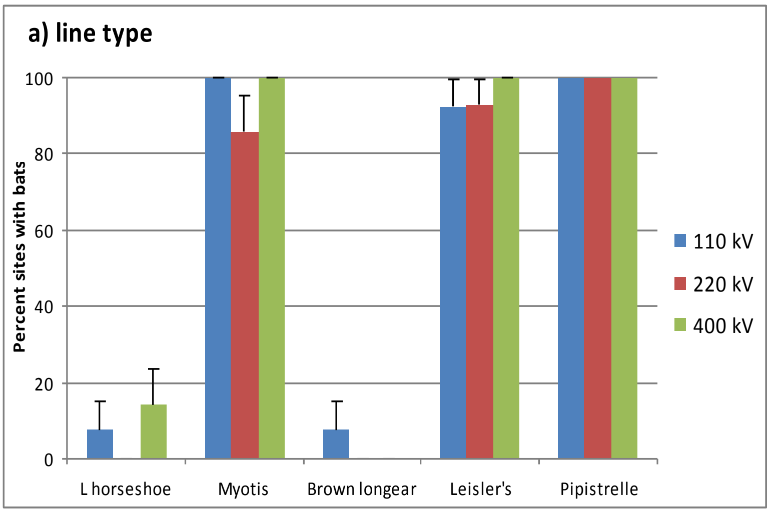
Common or soprano pipistrelles were recorded at all sites: 400 kV, 220 kV and 110 kV towers. Leisler's bat and *Myotis* spp. were recorded at all 400 kV tower sites. *Myotis* spp. was recorded at all 110 kV tower sites. Brown long-eared bat was recorded at a single site. Lesser horseshoe was recorded at 3 of the 10 sites: 2 at 400 kV towers (Ballygeagin 10L416; Applefort 10L426) and 1 at 110 kV towers (Ballymacloon 10L124).

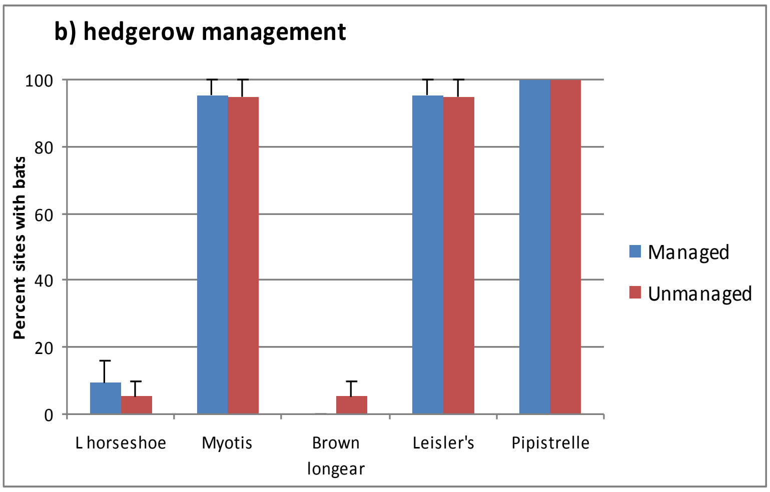
Figure 4.3 shows the percentage of sites with each bat species (or species group) present for each factor of interest. For line type (Figure 4.3a) none of the differences are statistically significant, although numbers of sites with lesser horseshoe (LHS) or brown long-eared bats detected were too small to provide a reliable test. The same applies to hedgerow management (Figure 1.13b), again with no significant differences.

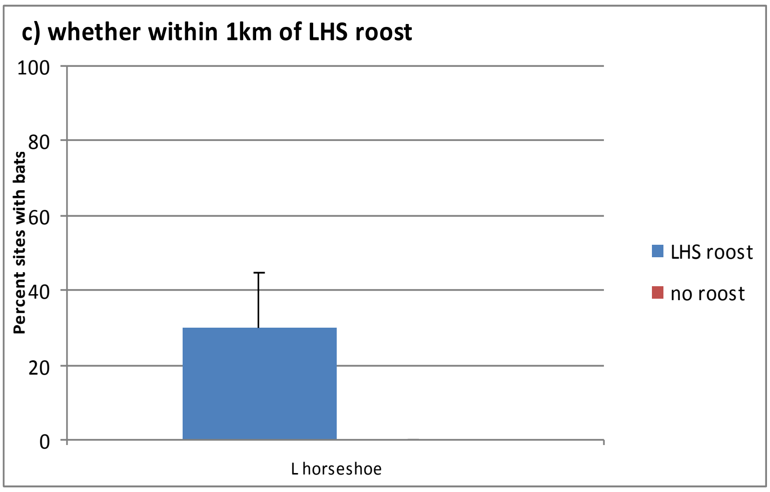
The only statistically significant difference in this series of analyses is that sites within 1 km of a LHS roost are more likely to have that species occurring (χ^2 = 9.25 with 1 d.f., P=0.001, Figure 1.13c).

Figure 4.3: Mean Percentage of Sites with Bats

Bars represent one standard error.







4.2.3 Hedgerow Management

Managed hedgerow was variable in terms of structure (height and width) and time lapse between cuttings. Some sites had just been recently cut, whilst others may have been three or more years since cutting. Hedgerow in arable lands tended to be most intensively managed. There was also variation in unmanaged sites in structure and species. Ash *Fraxinus excelsior* was the most frequently encountered hedgerow tree. One unmanaged site contained only hazel *Corylus avellana*.

Pipistrelle spp. were recorded at all managed and unmanaged sites. *Myotis* spp. were recorded at all but two sites - one managed and one unmanaged site (Cloughreagh (10L216) and Craigs (10L217)). Similarly, Leisler's bat was not recorded at two sites - one managed and unmanaged (Cloone (10L122) and Rosdoowan (10L218)). A single brown long-eared bat was recorded at an unmanaged site - Monaghan east (Tirfinnog (10L116)). At four sites, hedgerow had been cut as recently as September 2012 (10L227 Cunaberry; 10L228 Drisoge; 10L426 Applefort; 10L428 Boolinderry), and Pipistrelle spp., *Myotis* spp. and Leisler's bat were all recorded.

There were six managed and five unmanaged lesser horseshoe sites. Lesser horseshoe was found at three sites - two managed sites (400 kV & 110 kV towers) and one unmanaged (400 kV tower). The managed sites are Applefort, Co. Clare (400 kV tower) and Ballymacloon, Co. Clare (110 kV tower). The hedgerow at Applefort had been recently cut (see Appendix C25).

While it cannot be stated definitively whether bats recorded at these sites were commuting or foraging, their presence at these locations indicates that flight in the vicinity of managed or unmanaged hedgerows is occurring for all species groups. The presence of bats at these locations indicates that bats are active both in the vicinity of managed and unmanaged hedgerows. This serves as a proxy for OHL maintenance regimes along hedgerows.

4.2.4 Hedgerow Recovery

A note was taken at each site to describe any lasting impact of original hedgerow removal works where towers were located within hedgerows. Of the 28 towers that occurred in hedgerows, approximately 11 demonstrated some long-term and/or permanent loss of tree/shrub component. Six of these sites had a tree/shrub component loss ≥10m. These are Liscarnan (10L117), Belmont (10L121), Clonsilla East (10L127), Ballyrahan (10L128), Rinn (10L221) and Rathluby (10L421) (coloured red in Appendix C2 – C4).

Despite this considerably elongated break, Leisler's bat, Pipistrelle spp. and *Myotis* spp. were recorded at each of these 6 sites. The extent of hedgerow removed was notable at Clonsilla East (10L127) and Ballyrahan (10L128) where infrastructure had been recently erected. However, the aforementioned species were still recorded, despite there being a new and considerably elongated break, greater than 10m. Only 1 of the 10 lesser horseshoe sites (Rinn 10L221) had tree/scrub component loss ≥10m. No lesser horseshoe bats were recorded at this site.

5 DISCUSSION OF RESULTS AND CONCLUSIONS OF STUDY

5.1 DO OVERHEAD LINES AFFECT BATS?

The literature review revealed no significant findings pertaining to habitat removal, fragmentation and disturbance associated with the construction or operation of transmission lines.

The review affirms the importance of utilising best practice and habitat / species sensitive construction methodologies for new transmission line projects. For example, best practice would require trees with the potential for bat roosts to be identified, and preconstruction surveys undertaken, prior to felling.

Behavioural experiments have produced a large body of evidence to show that animals perceive the earth's natural magnetic fields. Published studies pertaining to bats and manmade EMF imply potential sensitivity to higher frequency EMF (i.e. frequencies significantly higher than that experienced around OHLs). A mammal study by Burda *et al.* (2009) found that low frequency electromagnetic fields appeared to disrupt magnetic alignment of ruminants (cattle and roe deer). However, these ruminants did not cease foraging at or near to OHLs.

A number of bat species exhibit magnetoreception. However, there is no literature showing any evidence that EMF generated by OHLs disrupts bat magnetoreception.

Literature on the effects of low frequency electromagnetic fields exposure on birds and other animal groups was also examined to infer possible impacts on bats. Bird studies are very limited, and those on wild birds fewer still. The extent and direction of effects are also unclear; some bird species, for example, appeared unaffected while others appeared negatively affected, and one study showed a positive response (although the positive effect may have been an indirect result of improved nesting opportunities at pylons).

There are fundamental physiological differences between birds and bats which further confounds making meaningful comparisons. While birds and bats are both capable of powered flight, bats are mammals with a vastly different biology (Willis *et al.*, 2009). For example, bats have already been shown to have inferior capacity to avoid wind turbine blades due to different respiratory system making them susceptible to 'barotrauma' (Bat Conservation Trust, 2009).

Tobin (2012) observed common and soprano pipistrelle and Leisler's bat actively foraging under towers and lines along existing hedgerow. At one of their study sites, a minimum of 5 common pipistrelles, 1 soprano pipistrelle, 1 Leisler and 2 unidentified species were observed close to OHL infrastructure, attracted by the local woodland habitat.

Overall, the presence or absence of suitable commuting and/or foraging habitat is the strongest determinant for bat activity of commoner species, around and adjacent to OHLs. Therefore, retaining existing high quality linear features or re-instating (and potentially enhancing) linear features where construction necessitates removal should offset any potential adverse impact on bats.

Overhead line (OHL) development is only one technology used in the development of electricity transmission lines. It is considered that underground cable (UGC) has the potential to have a greater impact on habitats, as the area of habitat removal and disturbance is greater in order to facilitate trench digging. Habitat removal for OHL is limited to the areas around the base of towers and pole sets and access routes. OHL projects have overall a very small physical footprint in terms of actual habitat removal compared to other linear projects such as road construction.

5.2 DOES THE PRESENCE AND OPERATION OF OVERHEAD LINES AFFECT BAT ACTIVITY?

5.2.1 Driven Transect Survey

This part of the study provides evidence that most Irish species are active in the vicinity of OHLs, particularly common and soprano pipistrelle and Leisler's bats. *Myotis* bats were also recorded in the vicinity of OHLs during the study.

During the study, on two occasions, common pipistrelle was observed foraging up and down directly below the overhead lines. This concurs with sightings in a separate study (Tobin, 2011) who found *P. pipistrellus*, *P. pygmaeus*, *Nyctalus leisleri* and unidentified species foraging under lines and tower infrastructure.

Distance from the OHL was not a significant predictor of the likelihood of bat occurrence, as bats were recorded at all distances from 0-500m from OHLs. There is an increasing likelihood (though not a significant one) for bats to be present on roads with more tree cover. Russ *et al.* (2003) found pipistrelle spp. activity was high in areas where tree line bordered one side of the road and particularly when bordering both sides of the road. This is not surprising, as most Irish species show strong associations with broadleaved woodland (Lundy *et al.*, 2011). This effect is adjusted for other factors such as distance from the OHL and line type.

This part of the study yielded a considerable dataset of bat activity and showed evidence of bat presence at all OHL sites sampled, irrespective of line voltage. Also, since there was no sign of an increase in bat activity with increasing distance from the power line, this study provides no evidence that the presence of high voltage power lines are eliciting a deterrent effect on bats.

5.2.2 Automated Passive Survey

In this study common and soprano pipistrelle occurred together at almost all sites. Leisler's bat and *Myotis* spp. were identified at the majority of sites. The brown long-eared bat was identified at a single site. The lesser horseshoe bat was more likely to occur at a passive monitoring site if the site was located within 1km of a known roost.

Detector surveys may not be the best means by which to survey for *Rhinolophus hipposiderus* since this species echolocates at a very high frequency (110 kHz). However, its presence at transmission infrastructure sites is encouraging. Brown long-eared bat obtains prey by gleaning insects off surfaces such as leaves and twigs (as well as catching prey in flight) (Russ, 2012). This may explain its presence at unmanaged hedgerows. These hedgerows will have increased surface area (leaves and twigs) upon which this species can forage.

Entwistle *et al.* (2001:p12) state that, *'even gaps as small as 10m may prevent bats using hedgerows and treelines'*.

Several passive monitoring study sites demonstrated long-term or permanent loss of the hawthorn /tall tree component; six of these were ≥10m. Most of the 'gaps' were more accurately a break in the occurrence of hawthorn, blackthorn, elder or larger tree species. Some sites comprised raised earth banks or stone walls supplemented with typical hedgerow trees. Where trees were removed, smaller shrubby species tended to proliferate, notably bramble and rank grasses typical of field margins. Despite the lack of tall vegetation, bats were still recorded at all of these sites.

The placement of electrical transmission infrastructure on or adjacent to linear features does not, therefore, appear to deter bats. Bats were also observed to be present at sites where infrastructure had been recently erected. This result is in keeping with the results of a more limited study conducted by Tobin for EirGrid (2011) where bat activity was recorded under 400kV towers that were installed across field boundaries and hedgerows.

While it cannot be stated definitively whether bats recorded at these sites were commuting or foraging, their presence at these locations indicates that bat flight is occurring in the vicinity of towers.

The presence of bats at these sites indicates that OHL infrastructure does not displace bats.

5.2.2.1 Hedgerow Management

No differences were found in the likelihood of a species or species group being present depending on hedgerow management regime.

Lesser horseshoe bat was recorded at two managed and one unmanaged site (Figure 5.1). One of these managed hedgerow sites was recently cut beneath a 400 kV tower (Figure 5.2).

It is possible however, that subtle differences in individual species' requirements may be masked by grouping species, as was done for the purposes of this study. For *Myotis* spp, difficulties distinguishing to species level using recorded sound files could only be overcome by trapping bats at study sites and carrying out identification in the hand.

Figure 5.1: 400 kV tower in ‘managed’ hedgerow at Applefort, Co Clare (Site 10L426)

(Despite being cut as recently as September 2012, lesser horseshoe, common pipistrelle, soprano pipistrelle, Myotis spp. and Leisler’s bat were all recorded).

Figure 5.2: 400 kV tower in ‘unmanaged’ hedgerow at Ballygeagin, Co. Galway (Site 10L416)

(Along this field boundary trees have been allowed to mature naturally. Lesser horseshoe, common pipistrelle, soprano pipistrelle, Myotis spp. and Leisler’s bat were all recorded).

Hedgerow avoidance by bats has been linked to intensive cutting of hedgerows into box shape form in Northern Ireland. This style of hedgerow gives flying insects (and bats) little protection from winds (Russ *et al.*, 2003). Intensively managed hedgerows in this current study may have reduced insect populations, although it is not possible from the present dataset, to determine whether recorded bats were foraging or commuting.

The absence of trees may reduce insect availability since certain tree species may have strong insect association and thus indirectly increase the food supply for bats. Indeed, based on their morphology and/or species composition it may be entirely appropriate to completely avoid hedgerow removal when considering the impacts on bats. However, because cutting associated with tower structure only occurs beneath that structure, the impact is localised. It does not equate to widespread or landscape-level intensive hedgerow management.

These studies therefore affirm potential benefits of retaining a mosaic of tree - scrub habitat types post disturbance. However, as part of the process of planning and design of new transmission projects in Ireland, every effort is made to avoid broadleaved woodland where possible in the first instance.

6 RECOMMENDATIONS

This Study gives no indication that the level of common pipistrelle, soprano pipistrelle or Leisler's bat activity is lowered along roadside close to OHL or that these species of bat cease to fly under pylons where they straddle hedgerows. Clearly this is welcome from the point of view of overall landscape-scale bat conservation in relation to electricity infrastructure in Ireland.

As the results of this original research have not concluded any detectable negative effect, no specific recommendations to inform future or updated evidence-based guidelines can be made. However, based on surveyor observations at the study sites, recommendations can be made pertaining to ecological assessment and mitigation within the planning, consenting and EIA regime, and construction stage techniques.

6.1 PRE-PLANNING, ASSESSMENT AND CONSTRUCTION

Assessing individual species' sensitivities on a local scale is important and should continue to remain a consideration at the scoping stage of Environmental Impact Assessment (EIA). In areas outside a species' core range (study sites in this instance were chosen from areas likely to be favourable for all bat species), bats may rely on small areas of favourable habitat, for example a small network of suitable tree roosts (N. Roche *pers.comm.*).

EirGrid's *Ecology Guidelines* for electricity transmission projects (2012) note that bat survey may be required depending on foraging or commuting habitat, specific to individual projects.

Desktop data collection on environmental constraints may reveal small areas of favourable foraging and/or commuting habitat networks at a small scale as transmission line route corridors are developed. This can be further explored as projects develop and more detailed ecological survey requirements emerge.

Trees will inevitably need felling to facilitate construction access or subject to long-term management during the operational phase of the development. While the knowledge-base relating to Irish bat fauna roosting in buildings and other manmade structures is reasonably well developed, the tree roosting habits of Irish bats are much less well known. Ecologists should continue to be vigilant when assessing features of trees used as bat roosts.

Following from the draft *Methodology for the recording of hedgerow extent, species composition, structure and condition in Ireland (*Murray and Foulkes, 2006), a refined hedgerow assessment methodology is now available. The Hedgerow Appraisal System (HAS) developed by Foulkes *et al.* (2013) has a tool to assess 'hedgerow significance' in an 'historical, ecological and landscape' context. The 'ecological' criteria of this HAS are particularly pertinent to bats, and include the following: tree, shrub and climber diversity; structure, construction and associated features; and habitat connectivity. Each criterion is ranked on a scale of 0-4, ranging from 'low significance' to 'high significance'. Such an appraisal system is recommended to help predict the impact of hedgerow removal.

The severance of plantation forest for any new transmission line projects should be seen as an opportunity for habitat enhancement. It is acknowledged that enhancement will need landowner consent as these wayleaves are not owned by EirGrid or the ESB. The Elia Life project (September 2011 – August 2016) in Belgium and France may help inform a similar initiative in Ireland.

In this study, particular attention was paid to how sections of hedgerow responded to disturbance/removal over time post-tower construction. Findings of this Study complement all recommendations made by Tobin (2011) for minimising impacts to hedgerow habitat in a previous EirGrid commissioned report.

Based on the findings of this study, two of these recommendations from the Tobin study are particularly pertinent to proposed hedgerow removal:

- *'Given the relatively small foundation footprint of towers, minimise as far as possible the length/volume of woody vegetation clearance'*

- *'..where complete clearance including significant disturbance is required, replant hedgerow around tower or other suitable location close-by (in agreement with landowner) with the objective of retaining the integrity of the impacted hedgerow. Species should be low growing woody vegetation species similar to those in remaining hedgerow and preferably of local provenance'.*

In considering this, regard would have to be had to the Forest Service *Forest Standards and Procedures Manual* (January 2015). Section 7 of the Manual deals with ESB corridors in forest plantation, and states that in such corridors, trees may be grown to a height of no more than 3m above the ground. Trees exceeding 3m within such corridors must be cut or lopped by the landowner. In addition, a corridor of 4m must be left totally clear for ESB maintenance access.

Notwithstanding this, based on the precautionary principle, the second recommendation of the Tobin study would ensure speedy re-establishment of woody vegetation linking intact hedgerow either side of the tower. This will hasten the return of any potentially vulnerable species, such as the lesser horseshoe bat. This may be particularly pertinent where a hedgerow or treeline used for foraging lies within range of a lesser horseshoe roost. The lesser horseshoe normally forages within a few kilometres of its roost (Bontadina *et al.*, 2002; Motte & Libois, 2002 cited in NPWS, 2013).

Implementation of these recommendations will have a potential benefit to all bats and other wildlife.

As far as possible, mitigation by avoidance will best serve bats. Placing towers adjacent to hedgerows will be inevitably better in the short term, particularly hedgerows with moderate to high ecological and/or connectivity value (Foulkes *et al.*, 2013).

Supplementary planting as a mitigation measure to provide biodiversity gain should be considered (with landowners' agreement) where remnants of native semi-natural woodland or disconnected hedgerow networks in the wider area along a proposed OHL corridor occur.

In terms of potential for impact on bats from noise and light, normal construction schedules for transmission infrastructure development should continue to restrict noise producing activities to daytime hours, so that foraging is likely to be unaffected. This also negates the need for artificial light. In addition, it is the case that such works are very much temporary in nature; poles can be erected in a day and towers over a period of a few weeks with only intermittent activity during this phase).

6.2 POTENTIAL FOR FURTHER STUDIES

Since bat activity levels are highly variable, repeat surveys at the same locations are unlikely to yield identical data. Deploying survey effort multiple times over a season, or if feasible over a number of years, would greatly increase the likelihood of detecting real trends, should they exist. Furthermore, the statistical power of any subsequent analysis could be improved either by counting bat passes by species, or by dividing the recording period into a number of intervals (maybe one minute periods) and recording the number of these with bat activity.

In addition, it is recommended that any future survey aligned to this study randomise the direction of travel for driven survey method, starting half the surveys at the overhead line and the other half at 500m. This will help account for variation in activity patterns with time. For passive sampling sites it would be ideal to include control sites in the study for comparative purposes.

The grouping of species means that subtle differences in the needs of sensitive species *may* be masked. This could only be overcome by carrying out a study which includes 'in the hand' identification, preferably with trap sampling to distinguish *Myotis* to species level. This would ensure that requirements of rarer and potentially more vulnerable Myotis species, such as the whiskered bat, would also be factored into the results. There is therefore potential to undertake trap sampling of bats (under licence) at sampling sites to confirm species identification, and insure that less detectable species are not missed.

Ecological monitoring may occur at wayleaving and construction stage, particularly if in compliance with a condition of statutory consent. This is dealt with in EirGrid's Ecology Guidelines (EirGrid, 2012). Future studies could be aligned with post-construction bat monitoring for a project if a bat assessment predicts particular impacts associated with bats.

7 REFERENCES

Alfonso Balmori Martinez (2003) Report on *The effects of microwave radiation on the wildlife: Preliminary results* [online], available: http://www.emrpolicy.org/litigation/case_law/beebe_hill/balmori_wildlife_study.pdf [accessed 19 Nov 2012].

Altringham (2003) *British Bats*, London: Harper Collins.

Altringham (2003) *British Bats*, London: Harper Collins **cited in** Andrews H. *et al.* (2013) *Bat Tree Habitat Key*, 2nd ed., AEcol Ltd, Bridgwater, available: http://www.aecol.co.uk/Pages/41/Downloads.html [accessed 22/01/2013].

Altringham (2011) *Bats: from evolution to conservation*, 2nd ed., New York: Oxford University Press.

Andrews H. *et al.* (2013) *Bat Tree Habitat Key*, 2nd ed., AEcol Ltd, Bridgewater, available: http://www.aecol.co.uk/Pages/41/Downloads.html [accessed 22/01/2013].

Arnett, E.B. (2005) Relationships between bats and wind turbines in Pennsylvania and West Virginia: an assessment of bat search protocols, patterns of fatality, and behavioral interactions with wind turbines. A final report submitted to the Bats and Wind Energy Cooperative, Bat Conservation International, Austin, Texas, USA **cited in** Nicholls & Racey (2007) 'Bats avoid radar installation: could electromagnetic fields deter bats from colliding with wind turbines?', *PloS ONE*, 3: e297.

Balmori, A. (2009) 'Electromagnetic pollution from phone masts. Effects on wildlife', *Pathophysiology*, 589:1-9.

Bat Conservation Ireland – NPWS (2007) Background to the conservation assessment of lesser horseshoe bat (*Rhinolophus hipposideros*) (Bechstein) in Ireland.

Bat Conservation Trust (2009) *Scoping and development report: determining the potential impact of wind turbines on bat populations in Britain*, London: Bat Conservation Trust.

Bat Conservation Trust (2011) The potential impact of radio frequencies and microwaves on wildlife, available: http://www.bats.org.uk/publications_download.php/1010/Radiowaves_and_bats_2011.pdf [accessed 06/02/2012].

Begall, S., Cerveny, J., Neef, J. Vojtech, O. and Burda, H. (2008) 'Magnetic alignment in grazing and resting cattle and deer', *Proceedings of the National Academy of Sciences of the United States of America*, 105: 13451-13455 **cited in** Burda, H., Begall, S., Cerveny, J. Neef, J. and Nemec, P. (2009) 'Extremely low-frequency electromagnetic fields disrupt magnetic alignment of ruminants', *Proceedings of the National Academy of Sciences of the United States of America*, 106(14): 5708-5713.

Berman, E., Chacon, K.L., House, D., Koch, B.A., Koch, W.E., Leal, J., Lovtrup, S., Mantiply, E., Martin, R.H. *et al.* (1990) 'Development of chicken embryos in a pulsed magnetic field', *Bioelectromagnetics*, 11: 169-187.

Bontadina, F., Schofield, H. and Naef-Daenzer, B. (2002) Radio tracking reveals that lesser horseshoe bats (Rhinolophus hipposideros) forage in woodland, *Journal of Zoology*, 258: 281-290 **cited in** NPWS (2013) *The Status of EU Protected Habitats and Species in Ireland, Species Assessments Volume 3*, Version 1.0, Unpublished Report [online], available at: http://www.npws.ie/publications/article17assessments/article172013assessmentdocuments/Article_17_Web_report_species_v1.pdf [accessed: 07/01/2014].

Berthinussen, A. and Altringham, J. (2012) 'The effects of a major road on bat activity and diversity', *Journal of Applied Ecology*, 49: 82-89.

Biggane, S. (2003) *The lesser horseshoe bat (Rhinolophus hipposideros) at Dromore, Co. Clare: Diet foraging activity, habitat selection and nocturnal behaviour*, PhD Thesis, University of Galway **cited in** Biggane S. (2004) *Investigation of the commuting routes and foraging activity of lesser horseshoe bats at four maternity roosts in Co. Clare*, Unpublished Report to National Parks and Wildlife Service.

Boonman, M. (2000) Roost selection by noctules (*Nyctalus noctula*) and Daubenton's bats (*Myotis daubentonii*)', *Journal of Zoology*, 251(03): 385-389.

Boughey, K.L., Lake, I.R., Haysom, K.A. and Dolman, P.M. (2011) 'Improving the biodiversity benefits of hedgerows: How physical characteristics and the proximity of foraging habitat affect the use of linear features by bats', *Biological Conservation*, 144(6), 1790-1798.

Brandt, G., Blows, L., Linton, D., Paling, N. and Prescott (2007) 'Habitat associations of British bat species in lowland farmland within the Upper Thames catchment area', *Centre for Wildlife Assessment & Conservation - E-Journal*, 1: 10-19.

Buckley, D.J., Rogan, E. and Butler, F.T. (2007) 'The habitat preferences of vespertilionid bats in lowland mixed use landscape', *The Irish Naturalists' Journal*, 28 (12), 488-496.

Burda, H., Begall, S., Cerveny, J. Neef, J. and Nemec, P. (2009) 'Extremely low-frequency electromagnetic fields disrupt magnetic alignment of ruminants', *Proceedings of the National Academy of Sciences of the United States of America*, 106(14): 5708-5713.

Coote, L., Smith, G.F., Kelly, D.L. *et al.* (2008) Epiphytes of Sitka spruce (*Picea stitchensis*) plantations in Ireland and the effects of open spaces, *Biodiversity Conservation*, 17: 953-968.

Cummins, C.P. & Osborn, D. (2002) Report on *Non ionizing radiation and wildlife*: revised final draft, Unpublished.

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

Dedon, M., Byrne, S., Aycrigg, J. and Hartman (1989) *Bird mortality in relation to the Mare Island 115 Kv transmission line: progress report 1988/1989*, San Bruno, California: Department of the Navy, Western Division, Naval Facilities Engineering Command, Office of Environmental Management.

Department of Environment, Heritage and Local Government (2002) National Spatial Strategy for Ireland 2002 – 2020, Dublin: the Stationary Office.

Doherty, P.F. and Grub, T.C. (1996) ‘Effects of high voltage power lines on birds breeding within the power lines’ electromagnetic fields’, *Sialia*, 18(4):129-143.

Eder, S., Cadiou, H., Muhamad, A., McNaughton, P., Kirschvink, J. and Winklhofer, M. (2012) ‘Magnetic characterization of isolated candidate vertebrate magnetoreceptor cells’, *Proceedings of the National Academy of Sciences of the United States of America*, early edition, available: http://www.pnas.org/content/early/2012/06/29/1205653109.full.pdf+html [accessed 14/01/2013].

EirGrid (2013) EMF & YOU: General Information about Electric & Magnetic Fields in Ireland, available: http://www.eirgridprojects.com/media/EMFInformationBooklet.pdf [accessed 29/10/2013].

EirGrid (2011) *Draft GRID25 Implementation Programme*, Dublin: EirGrid.

Environment & Heritage Service & National Parks & Wildlife Service (2008) *All Ireland Species Action Plan, Bats*, April 2008, available: <http://www.doeni.gov.uk/niea/batsallirelandsapmbwebversionapril2008-4.pdf>. [accessed 04/04/2012].

Environmental Impact Services Ltd (2011) Report on *Environmental Report for the Draft Grid25 Implementation Programme Strategic Environmental Assessment*, Dublin: EirGrid.

Entwistle, A. C., Harris, S., Hutson, A. M., Racey, P. A., Walsh, A. and Gibson, S. D. (2001). Habitat management for bats: A guide for land managers, land owners and their advisors, Peterborough, England: Joint Nature Conservation Committee.

Fenton M.B. (1997). Science and the conservation of bats, *Journal of Mammology*, 78: 1-14.

Fernie, K.J. and Bird, D.M. (1999) Effects of electromagnetic fields on body mass and food intake of American Kestrels, *Condor*, 101:616-621.

Fernie, K.J. and Bird, D. M. (2000) ‘Effects of electromagnetic fields on the growth of nestling American Kestrels’, *The Condor*, 102: 461-465.

Fernie, K.J. and Bird, D.M. (2001) ‘Evidence of oxidative stress in American kestrels exposed to electromagnetic fields’, *Environmental Research*, 86: 198-207 **cited in** Fernie, K.J. & Reynolds, S.J. (2005) ‘The Effects of Electromagnetic Fields from Power Lines on Avian Reproduction Biology and Physiology: A Review’, *Journal of Toxicology and Environmental Health*, Part B, 8(2), 127-140.

Fernie, K.J. and Reynolds, S.J. (2005) ‘The Effects of Electromagnetic Fields from Power Lines on Avian Reproduction Biology and Physiology: A Review’, *Journal of Toxicology and Environmental Health*, Part B, 8(2), 127-140.

EirGrid. (2012) Ecology Guidelines for Electricity Transmission Projects - A Standard Approach to Ecological Impact Assessment of High Voltage Transmission Projects. EirGrid, Dublin.

Forestry Commission (2005) *Woodland Management for Bats*, Wetherby: Forestry Commission.

Foulkes, N., Fuller, J., Little, D., McCourt, S and Murphy (2013) *Hedgerow Appraisal System – Best Practice Guidance on Hedgerow Survey, Data Collation and Appraisal*, Woodlands of Ireland, Dublin. Unpublished Report [pdf].

Griffin, D.R. (1958) *Listening in the dark*, New Haven: Yale University Press.

Grindal, D. and Brigham, R.M. (1998) ‘Short term effects of small scale habitat disturbance on activity by insectivorous bats’, *The Journal of Wildlife Management*, 62(3): 996-1003.

Gustafson, Y. and Schnitzler, H.-U. (1979) ‘Echolocation and obstacle avoidance in the Hipposiderid bat *Asellia tridens*’, *Journal of Comparative Physiology A*, 131: 161-167.

Hayes, J.P. (1997) ‘Temporal variation in activity in activity of bats and the design of echolocation-monitoring studies’, *Journal of Mammalogy*, 78(2): 514-524.

Hamann, H.-J., Schmidt, K.-H. and Wiltschko, W. (1998) ‘Possible effects of electric and magnetic fields on the breeding biology of birds using the example of a population of cave-nesting songbirds near a power line’, *Vogel und Umwelt*, 9(6): 215-246.

Harris, S. and Yalden, D.W., eds. (2008) *Mammals of the British Isles: handbook*, 4th ed., Southampton: The Mammal Society.

Holland, R.A., Kirschvink, J.L., Doak, T.G. and Wikelski, M. (2008) ‘Bats use magnetite to detect the Earth's magnetic field’, *PLoS ONE*, 3(2), e1676.

Hopkirk, A. and Russ, J. (2004) *Pre-hibernal and hibernal activity and dispersal patterns of Leisler’s bat* Nyctalus leisleri *in Northern Ireland*. Final Report to the Environment and Heritage Service of Northern Ireland **cited in** Harris, S. and Yalden, D.W., eds. (2008) *Mammals of the British Isles: handbook*, 4th ed., Southampton: The Mammal Society.

Holland, R.A., Thorup, K., Vonhof, M.J., Cochran, W.W. and Wikelski, M. (2006) 'Bat orientation using Earth's magnetic field', *Nature*, 444(7): 653-702.

ICNIRP - International Commission on Non Ionising Radiation Protection (1998) Report on Guidelines for limiting exposure to the time-varying electric, magnetic, and electromagnetic fields (up to 300GHz), *Health Physics*, 74(4): 494-522.

Janss, G.F. (2000) 'Avian mortality from power lines: a morphological approach of a species specific mortality', *Biological Conservation*, 95:353-359.

Jones, K.E., Purvis, A. and Gittleman, J.L. (2003) 'Biological correlates of extinction rates in bats', *American Naturalist*, 161: 601-614 cited in Altringham (2011) *Bats: from evolution to conservation*, 2nd ed., New York: Oxford University Press.

Juutilainen, J. (2005) Developmental effects of electromagnetic fields, *Bioelectromagnetics*, 26(70: 107-115.

Kelleher, C., Marnell, F. (2006) Bat Mitigation Guidelines for Ireland. Irish Wildlife Manuals, No. 25. National Parks and Wildlife Service, Department of Environment, Heritage and Local Government, Dublin.

Lee, D.N., van der Weel, F.R., Hitchcock, T., Matejowsky and Pettigrew, D. (1992) 'Common principal of guidance by echolocation and vision', *Journal of Comparative Physiology A*, 171:563-571.

Lee, Y. and Nelder, J.A. (2001) 'Hierarchical generalised linear models: a synthesis of generalised linear models, random-effect models and structured dispersions', *Biometrika*, 88: 987-1006.

Life Elia (2011) *Developing the corridors beneath electricity transmission lines as a means of enhancing biodiversity* [online], available at: http://www.life-elia.eu/en/Project-actions [accessed: 1401/2013].

Limpens, H., Helmer, A.W., Van Winden, A. and Mostert, K. (1989) 'Bats (Chiroptera) and linear landscape elements. A review of our present knowledge of the importance of linear landscape elements to bats', *Lutra*, 32(1):1-20.

Lohmann, K.J. (2010) 'Magnetic-field perception', *Nature*, 464(22), 1140-1142.

Lucan, R.K., Hanak, V. and Horacek, I. (2009) 'Long term re-use of tree roosts by European forest bats', *Forest Ecology and Management*, 258(7): 1301-1306.

Lundy, M.G., Aughney, T., Montgomery, W.I. and Roche, N. (2011) *Landscape conservation for Irish bats & species specific roosting characteristics*, Cavan: Bat Conservation Ireland.

MacLennan (*ed.*) (2004) *Opportunities for biodiversity enhancement in plantation forests*, COFORD: Dublin.

McAney, K. (2006) A conservation plan for Irish vesper bats, Irish Wildlife Manuals, No. 20, National Parks and Wildlife Service, Department of Environment, Heritage and Local Government, Dublin, Ireland.

Menzel, M.A., Carter, T.C., Menzel, J.M., Ford, W.M. and Chapman, B.R. (2002) 'Effects of group selection silviculture in the bottomland hardwoods on the spatial activity patterns of bats', *Forest Ecology and Management*, 162(2-3): 209-218.

Motte, G. and Libois, R. (2002) Conservation of the lesser horseshoe bat (Rhinolophus hipposideros) in Belgium: a case study of feeding habitat requirements, *Belgian Journal of Zoology*, 132(10): 49-54 **cited in** NPWS (2013) *The Status of EU Protected Habitats and Species in Ireland, Species Assessments Volume 3*, Version 1.0, Unpublished Report [online], available at: http://www.npws.ie/publications/article17assessments/article172013assessmentdocuments/Article_17_Web_report_species_v1.pdf [accessed: 07/01/2014].

National Parks & Wildlife Service (2008) '*The Status of EU Protected Habitats and Species in Ireland'*, National Parks & Wildlife Service, Dublin: Department of the Environment, Heritage & Local Government.

Northern Ireland Electricity (NIE) (2009) 'electric field strength underneath the proposed overhead line at differing load levels and resulting minimal ground clearances', *Tyrone – Cavan 400 kV Interconnector Overhead transmission line project*, Volume 2, Belfast: RPS, illus. 7.3.

NPWS (2009) *Threat Response Plan: Vesper bats (2009-2011),* National Parks & Wildlife Service, Department of the Environment, Heritage & Local Government, Dublin.

Orbach, D.N. and Fenton, B. (2010) 'Vision impairs the abilities of bats to avoid colliding with stationary obstacles', *PloS One*, 5(11): 1-7.

Patriquin, K.J. and Barclay, R.M.R. (2003) 'Foraging by bats in cleared, thinned and unharvested boreal forest', *Journal of Applied Ecology*, 40: 646-657.

Racey, P.A., Swift, S.M. and Avery, M.I. (1985) 'Feeding ecology of *Pipistrellus pipistrellus* (Chiroptera: Vespertilionidae) during pregnancy and lactation. II. Diet', *The Journal of Animal Ecology*, 54(1): 217-225.

Richardson, P. (2011) Bats and hedgerows – are bat surveyors on the right track? In Practice 74:28-30.

Russ, Jon. (2012) *British bat calls: a guide to species identification*, Exeter: Pelagic Publishing.

Russ, J. (1999) *The bats of Britain and Ireland: echolocation calls, sound analysis, and species identification*, Place of Publication Unknown: Alana Ecology.

Russ, J.M., Briffa, M. and Montgomery, W.I. (2003) 'Seasonal patterns in activity and habitat use by bats (*Pipistrellus* spp. and *Nyctalus leisleri*) in Northern Ireland, determined using a driven transect', *Journal of Zoology*, 259: 289-299.

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

Schaub, A., Ostwald, J. and Siemers, B.N. (2008) Foraging bats avoid noise, *Journal of Experimental Biology* **cited in** Altringham (2011) *Bats: from evolution to conservation*, 2nd ed., New York: Oxford University Press.

Schofield, H.W. (1996). The ecology and conservation biology of *Rhinolophus hipposideros*, the lesser horseshoe bat, PhD thesis, University of Aberdeen.

Solov'yov, I.A. and Greiner, W. (2009) 'Iron-mineral-based magnetoreceptor in birds: polarity of inclination compass?', *The European Physical Journal D*, 51: 161-172.

Steenhof, K., Kochert, M. N. and Roppe, J.A. (1993) 'Nesting by raptors and common ravens on electrical transmission line towers', *Journal of Wildlife Management*, 57: 271-281.

Sterry, P. (2007) *Collins complete guide to British Trees*, London: Collins.

Tobin Consulting Engineers (2011) *Benchmark Hedgerow s*tudies, Dublin: Tobin Consulting Engineers.

Wang, Y., Pan, Y., Parsons, S., Walker, M. and Zhang, S. (2007) 'Bats respond to polarity of a magnetic field', *Proceedings of the Royal Society, B*, 274, 2901-2905.

Verboom and Huitema (1997) 'The importance of linear landscape elements for the pipistrelle *Pipistrellus pipistrellus* and the serotine bat *Eptesicus serotinus'*, *Landscape Ecology*, 12: 117-125.

Victorian Government Department of sustainability and Environment (2011) *Fact sheet: What to do when a electrocuted Grey-Headed Flying-fox is found* [online], available:http://www.dse.vic.gov.au/__data/assets/pdf_file/0020/135830/electrocuted-GHFF_factsheet_final_2012.pdf [accessed 24 June 2012].

Willis, C.K.R., Barclay, R.M.R., Boyles, J.G. *et al.* (2009) 'Bats are not birds and other problems with Sovacool's (2009) analysis of animal fatalities due to electricity generation', *Energy Policy*, Article in Press.

APPENDIX A

OVERVIEW OF ELECTRICITY TRANSMISSION INFRASTRUCTURE, INCLUDING TYPICAL CONSTRUCTION METHODOLOGY

A1 Description of Typical Electricity Transmission Project Designs

The transmission network in Ireland comprises structures and overhead lines, underground cables and substations. When the need for a new circuit is identified in Ireland, EirGrid will consider all available solutions for the new circuit. This will include overhead line and underground cable solutions, considering both High Voltage Alternating Current (HVAC) and High Voltage Direct Current (HVDC) technology, as appropriate.

Factors which will influence the solution decision include technical, economic and environmental considerations. It is important to note that each project is different and EirGrid will determine potential technology solutions on a project-by-project basis. EirGrid will continue to keep technology developments under review and will consider new technologies as appropriate.

A1.1 Overhead Lines (OHL)

Transmission lines are generally supported on either wooden pole sets or steel lattice towers. Towers along a straight of the alignment are known as intermediate towers. Angle towers are used where a line changes direction and conductors are held under tension.

The type and height of structures required will vary according to the voltage of the overhead line, and the location and type of environment and terrain in which they are placed.

A1.2 Structure Design

For all new electricity transmission projects, efficient, appropriately placed and optimally designed structures are carefully considered and proposed. The design employed depends on the local environment, topography and technologies involved, and will vary from 110 kV, 220 kV or 400 kV, depending on the specific transmission need identified.

The spacing between structures depends on technical limitations and on the topography, particularly to ensure that conductors maintain a specific minimum clearance above the ground at all times.

Steel Lattice Tower Structures

The weight of conductors and characteristics of 220 kV and 400 kV lines require that they be supported exclusively on lattice steel structures (this also applies to angle towers along a 110 kV line). The three phases (conductors) of a circuit are carried in a horizontal plane.

Table A1: Key Design Features: Single Circuit 220 kV and 400 kV overhead line structures

Key Design Features	220 kV Indicative Range	400 kV Indicative Range
Height range	Depends on technical details of individual projects but generally between 20-40m	Depends on technical details of individual projects but generally between 20m -52m
Maximum range of width at ground level	6m to 12m	7m to 12m
Number of foundations per structure	4	4
Average span between towers	Approx. 320m (dependent on local topography)	Approx. 350 (dependent on local topography)

Example of a 400 kV intermediate tower design along the Dunstown-Moneypoint overhead line, Co Clare

Example of a 220 kV intermediate tower design along the Cashla – Flagford overhead line, Co Roscommon

Single Circuit 110 kV Overhead Lines

A 110 kV single circuit overhead line requires that conductors (and earth wires[1]) are supported on a combination of steel lattice angle towers and double wood intermediate polesets.

The average span between polesets for a 110 kV single circuit alignment is approximately 180m; however, the actual span achievable depends on local topography. Again, the three phases of the circuit are carried in a horizontal plane.

Table A2: Key Design Features of Single Circuit 110 kV overhead line support structures

Key Design Features	110 kV Indicative Range
Height range (double wood polesets)	16m to 23m (incl. buried depth normally 2.3m)
Pole centres	5m
Number of foundations	2
Height range (steel angle towers)	18m to 24m
Maximum width at ground level	4m to 9.8m
Average span	180m

Example of a typical 110kV single-circuit double wood polesets with earthwire (Co Sligo)

On an alignment there may arise a very slight change in direction, and this may necessitate, in the case of a 110 kV single-circuit line, the use of a braced wood poleset, wherein the space between the polesets is reinforced with steel members.

[1] Lines running above the conductors which protect the conductors from lightning strike.

Braced double wood poleset

Double Circuit Overhead Lines

Overhead alignments can be configured as single circuit or double circuit (two separate circuits supported on a single structure). This generally only occurs where two single circuit lines are in close proximity (for example on approach to a substation), or where space is at a premium.

Double circuit alignments, including 110 kV overhead lines, always require to be supported by lattice steel towers. The average number of structures on a line is 3-4 per km depending on topography. In addition, the structures are higher, as each circuit must be carried in a vertical plane.

Typical 110 kV double circuit structures

A1.3 Construction of Overhead Lines

Overhead line construction typically follows a standard sequence of events comprising:

- Prepare access;
- Install tower foundations/Excavation;
- Erect towers or wood poles;
- Stringing of conductors;
- Reinstate tower sites and remove temporary accesses.

Prepare Access

It is preferable to have vehicular access to every tower site for foundation excavation, concrete delivery and a crane to erect towers. With wood pole construction, (on 110 kV single circuits) a crane is not usually required, as these are normally erected with a digger using a lifting arm.

Access can take various forms and is dependent on ground conditions. In poorer conditions, more complex access works are required which can vary from the laying of bog mats, or laying temporary wooden matting, to installing crushed stone roads. Some of this work may entail removal of topsoil.

Access routes may require to be constructed for both the construction and maintenance of the transmission line, and may be temporary or permanent.

Every effort is made to cause least disturbance to landowners and local residents, and to cause the least potential environmental impact during construction. As a result, the most direct access route to a tower installation may not always be the most appropriate.

Example of a newly built access route for a transmission project, Co. Donegal

Install Tower Foundations/Excavation

Tower foundations are typically 2–4m deep with excavation carried out by mechanical excavator. Excavations are set out specifically for the type of tower and the type of foundation required for each specific site.

A larger footing may be required in the case of weak soils. Pile foundations may be required in the case of deep bog. In the case of rock being encountered at shallow depths, reduced footing size foundations may be required.

Prior to excavation, the foundations for each tower site will be securely fenced off to ensure the safety of members of the public and livestock. Tower stubs (the lower part of the tower leg) are concreted into the ground. Once the concrete has been poured and cured, the excavation is back-filled using the original material in layers. Surplus material is removed from site.

The excavation required for a wooden poleset is typically 1.5m-2m x 3m x 2.3m deep; no concrete foundations are required for polesets in normal ground conditions. Installation time is approximately two per day. The average foundation size for a braced poleset is 9.3m x 3.1m x 3.2m deep.

In addition to the excavation required for the poleset itself, where ground conditions dictate, stay lines may be required. This generally involves excavation of four trenches (approximately 2m x 2m x 1.8–2m deep) at a distance from the poleset. The installation of stay wires expands the area of disturbance associated with the erecting a poleset.

Stay lines in place, Donegal 110 kV Project

Concrete foundations are required for all steel towers. Foundation size and type is dependent on ground conditions and tower type, but is typically 4m x 4m x 3.1m for each foundation pad. The base installation time is approximately one week.

110kV angle towers at Srananagh Station with exposed substructures

For all transmission lines with earth wires, there is a requirement to install an earth ring or mat at the base of the structure to ground the structure for safety reasons. The ground around the base of structures is excavated after conductors and earthwires are in place and the earth ring is installed.

Earth ring on Donegal 110kV Project

Erect Towers or Wood Poles
Materials required for construction are transported around the site by general purpose cross country vehicles with a lifting device. Excavators are generally of the tracked type to reduce likely damage to and compaction of the ground. In addition a temporary hard standing may be required for machinery and this may require the removal of topsoil. Materials are delivered to site storage/assembly areas by conventional road transport and then transferred to sites.

Tower erection can generally commence two weeks after the foundations have been cast. Tower steelwork is usually delivered to site and assembled on site.

Installation of tower using a derrick pole at the base

Construction of wooden poleset support structure for Donegal 110 kV Project (Binbane – Letterkenny)

Stringing of conductors
Once angle towers are erected, conductor stringing can commence, installing conductors from angle tower to angle tower via the line intermediate structures. Conductor drums are set up at one end of the straight with special conductor stringing machinery, and pulled from one end to the other.

Stringing Machine

Conductor stringing equipment

Reinstate tower sites and remove temporary accesses
The disturbed ground around a tower or poleset location is made good, and all temporary access materials generally removed.

A1.4 Line Uprating and Refurbishment

In general a transmission line requires little maintenance. It is periodically inspected to identify any unacceptable deterioration of components so that they can be replaced as necessary. A more detailed condition assessment on a line is usually carried out when it is approximately 35 years old.

The majority of the existing transmission grid was constructed after 1960; the majority of those lines constructed prior to 1960 have already been refurbished. There is an on-going programme of line refurbishment concentrating on older lines.

Refurbishment projects are condition based, and once a line has been identified for refurbishment, consideration is given to the potential opportunity to upgrade its carrying capacity or thermal rating. This might involve replacing existing conductors with modern conductors which, while having effectively the same diameter, can carry significantly greater amounts of electricity.

Often the additional weight of these replacement conductors means associated replacement of support structures with stronger structures. Where structures require replacement during a line upgrade or refurbishment, additional excavation may be required particularly where angle towers or structures require replacement. In general they are replaced within the footprint of the original structure.

Insulators and conductors are normally replaced after about 40 years, and towers are painted every 15-20 years or as necessary.

A1.5 Underground Cabling (UGC)

High voltage (HV) circuits can only be laid underground using special HV cables designed specifically for underground use. The conductors in underground HV cables must be heavily insulated to avoid a short circuit between the conductor and the ground around the cable.

Table A3: Key Design Features: Underground Cabling

Key Design Features	HV Cable (typical dimensions)
Cable Trenches	c.0.6m wide-1.25m deep for a 110 kV trench, c. 1.1m wide x 1.25m deep for 220 kV and 400 kV for a single cable
Joint Bays	6m long, 2.5m wide and 1.8m deep
Excavation trench for Joint Bay	7m long, 3m wide and 2m deep
Average span between joint bays	500m–700m
Directional Drill entry and exit pits	1m x 1m x 2m

The cable is installed directly into the ground in an excavated trench. The majority of high voltage cable routes are located along public roads and open spaces. It is very unusual for a cable route to cross private open ground but this may be the case on occasion. The civil contractor will scan the ground using a cable avoidance tool (CAT), carry out a visual inspection of existing services and compare the information with the utility service records which they will have obtained from the various service providers in advance. If any previously unidentified services are discovered the site engineer will adjust the cable route accordingly.

Typical 110kV Trench Excavation (Ducts in Trefoil Formation)

The overall installation of a cable route over a large distance is broken down into sections of cable that are connected using a cable joint. Cable joints are installed in joint bays which are typically concrete structures buried underground, occurring generally every 500–700m along an alignment, and ranging in size up to 6m long, 2.5m wide and 1.8m deep.

Typical Joint Bay Construction Adjacent to Public Road

If the cable was installed directly in the ground the entire trench from joint bay to joint bay must be fully excavated. The advantage with installing cable in pre-laid ducts is that only a short section of cable trench, up to 100m is open at any time. This helps to minimise the impact on the local residents and minimise traffic impact at any given time.

Typical HV Cable Installation

Once installed, the road surface is reinstated. Where a cable route is in an open area, it is returned to agricultural/grassland use. Where a cable passes through forested land the route is not replanted with trees to prevent any damage to the cable by tree root growth.

Re-growth following underground cable construction on agricultural land

A1.6 Substations

Substations connect two or more transmission lines; they take the electricity from the transmission lines and transform high to low voltage, or vice versa. They contain various electrical equipment, including voltage switches, transformers, protection equipment, and associated lines and cabling.

The siting of a substation depends on topography; the ground must be suitable to meet technical standards. With regard to earthing requirements and soil stability, substations are usually constructed on reasonably level ground, in areas that are not liable to flooding or crossed by significant watercourses.

A substation site is normally future proofed with the capability to be extended if the need arises.

Substations can take two forms:

An Air Insulated Switchgear (AIS) substation is where the electrical equipment infrastructure is primarily installed outdoors, with the use of natural air as an insulation between circuits. This option requires a relatively large compound footprint.

Srananagh 220kV/110kV substation, Co Sligo, example of a typical outdoor AIS substation

A Gas Insulated Switchgear (GIS) substation, is where gas (Sulphur Hexafluoride – SF6) is used as the insulation between circuits. This requires the electrical equipment to be contained internally, in buildings of some 11–13m over ground. This allows for a significantly smaller substation footprint.

Both options require the associated provision of access roads off and onto the public road network and the provision of associated electrical equipment and infrastructure (including underground cables), as well as ancillary waste water treatment facilities and other site development and landscaping works. Both are therefore significant civil engineering projects.

Example of a typical indoor GIS substation, Co Limerick

APPENDIX B

DRIVEN TRANSECT SURVEY

Date	Site Code	X	Y	Site Name	County	Bat Presence / Absence with Distance from OHL					
						0m	25m	50m	100m	200m	500m
28-Jul	10L101	254867	318648	Corraghary	Monaghan	0	1	1	0	0	1
28-Jul	10L102	253826	317549	Magherashaghry	Monaghan	1	1	0	1	1	1
07-Aug	10L103	142647	207963	Kinvara	Galway	1	1	1	1	1	1
27-Aug	10L104	145353	164689	Seersha	Clare	1	1	1	1	1	1
31-Aug	10L105	184661	220609	Skenageehy	Galway	1	1	1	1	1	1
04-Sep	10L106	149226	151630	Ferrybridge	Limerick	1	1	1	1	1	1
05-Sep	10L107	125096	146246	Shanagolden	Limerick	1	0	1	0	0	1
07-Sep	10L108	263243	127920	Ballalog	Kilkenny	0	0	0	1	0	1
19-Sep	10L109	148806	165071	Ballyliddan	Clare	1	1	0	0	1	0
19-Sep	10L110	144225	164552	Ardkyle	Clare	1	1	0	0	0	1
20-Sep	10L111	259661	151711	Clashwilliam	Kilkenny	1	0	1	1	1	1
20-Sep	10L112	263074	159856	Ballyvalden	Kilkenny	1	0	1	1	1	1
23-Sep	10L113	194802	229862	Rooty	Roscommon	1	0	0	0	0	0
28-Sep	10L114	168131	224489	Cara	Galway	1	1	0	1	0	0
28-Sep	10L115	194804	229860	Hillsend	Roscommon	0	0	0	0	0	1
						12	9	8	9	8	12

Driven Transect Sites 110 kV line

Date	Site Code	X	Y	Site Name	County	Bat Presence / Absence with Distance from OHL					
						0m	25m	50m	100m	200m	500m
19-Jul	10L201	293025	300477	Tallanstown	Louth	1	0	1	1	1	0
27-Jul	10L202	290882	297032	Reaghstown	Louth	1	1	1	1	0	1
07-Aug	10L203	140712	208495	Kinvara	Galway	1	0	1	1	1	1
17-Aug	10L204	189611	193092	Ballyfinbay	Tipperary	1	1	1	1	1	1
18-Aug	10L205	291183	260943	Tara	Meath	1	1	1	0	1	1
19-Aug	10L206	290110	285421	Howthstown	Meath	1	1	1	1	1	1
25-Aug	10L207	187608	187873	Ballythomas	Tipperary	1	1	1	1	1	1
25-Aug	10L208	189670	194908	Kyletombricklane	Tipperary	1	1	1	1	1	1
27-Aug	10L209	292453	296693	Arthurstown	Louth	1	0	0	1	1	1
29-Aug	10L210	53134	145811	Askeaton	Limerick	1	1	1	0	0	0
06-Sep	10L211	124207	167383	Toberaniddaun	Clare	1	1	1	1	0	1
07-Sep	10L212	255188	114460	Curraghmartin	Kilkenny	1	1	1	1	0	1
14-Sep	10L213	284171	164333	Sragh	Carlow	1	1	1	1	1	1
14-Sep	10L214	279920	159043	Knockdramagh	Carlow	1	1	1	1	1	1
23-Sep	10L215	208716	224541	Moyclare	Offaly	1	1	1	1	1	1
						15	12	14	13	11	13

Driven Transect Sites 220 kV line

Date	Site Code	X	Y	Site Name	County	Bat Presence / Absence with Distance from OHL					
						0m	25m	50m	100m	200m	500m
06-Aug	10L401	194921	209228	Glenbower South	Tipperary	1	1	1	0	1	1
06-Aug	10L402	194921	209228	Glenbower North	Tipperary	1	1	1	1	1	1
30-Aug	10L403	134348	171515	Lissan West	Clare	1	1	1	1	1	1
30-Aug	10L404	132159	170477	Islandavanna	Clare	1	1	1	0	1	1
30-Aug	10L405	131028	170214	Teermaclane	Clare	1	1	1	1	1	1
31-Aug	10L406	180678	208648	Coolpowra	Galway	0	1	1	0	1	1
06-Sep	10L407	128453	167999	Lisheen	Clare	1	0	0	1	1	1
06-Sep	10L408	127864	167353	Carhumeere	Clare	1	1	1	1	1	1
06-Sep	10L409	184330	174159	Kilmore North	Tipperary	1	1	1	1	1	0
07-Sep	10L410	178382	175257	Mountstack	Tipperary	0	0	0	0	0	0
12-Sep	10L411	177481	174742	Burges Bridge	Tipperary	0	1	1	1	1	1
13-Sep	10L412	162396	171249	Broadford	Clare	1	1	0	1	0	0
14-Sep	10L413	174022	172748	Balley North	Tipperary	1	0	1	1	1	1
15-Sep	10L414	175882	173818	Curraghmore	Tipperary	1	1	1	0	1	0
						11	11	11	9	12	10

Driven Transect Sites 400 kV line

EIRGRID

EirGrid Driven Bat Activity Survey Form	
Date:	
Surveyor:	
Sunset:	

Anabat Ref:	

Grid Ref (0 m):	
Grid Ref (25 m):	
Grid Ref (50 m):	
Grid Ref (100 m):	
Grid Ref (200 m):	
Grid Ref (500 m):	

Start Time:	
Start Temp:	

Wind:	Calm		Light		Breezy	
Cloud Cover:	Clear 0-1/3		Patchy 1/3-2/3		Full 3/3	
Rainfall:	Dry		Drizzle		Rain	

Grade	Habitat Type Key
1	Fence or wall lining road and open fields beyond.
2	Hedges/shrubby verges lining road and open fields beyond.
3	Intermittent medium trees/bushes lining road and open fields beyond.
4	Intermittent tall trees lining road and open fields beyond.
5	Continuous tree cover lining road with woodland and/or open fields beyond.

Survey Point	Habitat Type Grade
0 m	
25 m	
50 m	
100 m	
200 m	
500 m	

Finish Time:	
Finish Temp:	

SAMPLE

APPENDIX C

AUTOMATED PASSIVE MONITORING SURVEY

Site Code	X	Y	Site Name	County	Weather Station	Hedgerow	<1km LHS roost	Bat Presence/Absence				
								Lesser Horseshoe Bat	Pipistrelle Spp.	Myotis spp.	Brown Long-eared bat	Leisler's bat
10L116	271591	332934	Tirfinnog	Monaghan	Ballyhaise	Unmanaged		0	1	1	1	1
10L117	284334	296906	Liscarnan	Monaghan	Ballyhaise	Unmanaged		0	1	1	0	1
10L118	286292	272467	Silloge	Meath	Dunsany	Managed		0	1	1	0	1
10L119	286167	272277	Randalstown	Meath	Dunsany	Unmanaged		0	1	1	0	1
10L120	205306	296878	LaheenSouth	Leitrim	Mt. Dillon	Unmanaged		0	1	1	0	1
10L121	137344	263130	Belmont	Galway	Claremorris	Managed		0	1	1	0	1
10L122	217471	299394	Cloone	Leitrim	Mt. Dillon	Managed		0	1	1	0	0
10L123	137577	178993	Kilfeilim	Clare	Shannon	Managed	Yes	0	1	1	0	1
10L124	143945	173793	Ballymacloon	Clare	Shannon	Managed	Yes	1	1	1	0	1
10L125	150296	165728	Ballyroe	Clare	Shannon	Managed	Yes	0	1	1	0	1
10L126	249210	104839	Coolrattin	Waterford	Moorepark	Unmanaged		0	1	1	0	1
10L127	317002	163881	Clonsilla East	Wexford	Oak Park	Unmanaged		0	1	1	0	1
10L128	312896	160844	Ballyrahan	Wexford	Oak Park	Unmanaged		0	1	1	0	1
								1	13	13	1	12

Automated Passive Monitoring Sites 110 kV line

*Sites coloured red denote hedgerow with a gap ≥10 meters

Site Code	X	Y	Site Name	County	Weather Station	Hedgerow	<1km LHS roost	Bat Presence/Absence				
								Lesser Horseshoe Bat	Pipistrelle spp.	Myotis spp.	Brown Long-eared bat	Leisler's bat
10L216	283463	292509	Cloghreagh	Meath	Ballyhaise	Unmanaged		0	1	0	0	1
10L217	289569	272385	Craigs	Meath	Dunsany	Unmanaged		0	1	0	0	1
10L218	207610	295949	Rosdoowaun	Leitrim	Mt. Dillon	Unmanaged		0	1	1	0	0
10L219	206444	295558	Killamaun	Leitrim	Mt. Dillon	Managed		0	1	1	0	1
10L220	204536	293913	Cloonfinnan	Leitrim	Mt. Dillon	Unmanaged		0	1	1	0	1
10L221	144851	218547	Rinn	Galway	Mace Head	Managed	Yes	0	1	1	0	1
10L222	140714	213235	Ballymore	Galway	Mace Head	Unmanaged	Yes	0	1	1	0	1
10L223	140717	212184	Gortaboy	Galway	Mace Head	Unmanaged	Yes	0	1	1	0	1
10L224	189640	193850	Curraghmore	Tipperary	Gurteen	Unmanaged		0	1	1	0	1
10L225	247022	106235	Lissahane	Waterford	Moorepark	Managed		0	1	1	0	1
10L226	248727	109988	Cullenagh	Waterford	Moorepark	Managed		0	1	1	0	1
10L227	284045	167474	Cunaberry	Wexford	Oak Park	Managed		0	1	1	0	1
10L228	284315	167390	Drisoge	Wexford	Oak Park	Managed		0	1	1	0	1
10L229	287941	167681	Craans	Carlow	Oak Park	Managed		0	1	1	0	1
								0	14	12	0	13

Automated Passive Monitoring Sites 220 kV line

*Sites coloured red denote hedgerow with a gap ≥10 meters

Site Code	X	Y	Site Name	County	Weather Station	Hedgerow	<1km LHS roost	Bat Presence/Absence				
								Lesser Horseshoe Bat	Pipistrelle spp.	Myotis spp.	Brown Long-eared bat	Leisler's bat
10L415	144783	193978	Carheeny Beg	Galway	Shannon	Managed		0	1	1	0	1
10L416	142623	193349	Ballygeagin	Galway	Shannon	Unmanaged	Yes	1	1	1	0	1
10L417	138796	192314	Knockatermin	Clare	Shannon	Unmanaged	Yes	0	1	1	0	1
10L418	179493	207708	Kilcorban	Galway	Gurteen	Managed		0	1	1	0	1
10L419	184602	210742	Oldstreet	Galway	Gurteen	Managed		0	1	1	0	1
10L420	188018	211031	Cappagh	Galway	Gurteen	Unmanaged		0	1	1	0	1
10L421	146874	171798	Rathluby	Clare	Shannon	Unmanaged		0	1	1	0	1
10L422	147479	171578	Shandangan	Clare	Shannon	Managed	Yes	0	1	1	0	1
10L423	165957	171328	Knockaderreen	Clare	Shannon	Managed		0	1	1	0	1
10L424	174225	172862	Ballyea North	Tipperary	Shannon	Unmanaged		0	1	1	0	1
10L425	158461	171709	Crean	Clare	Shannon	Unmanaged		0	1	1	0	1
10L426	145550	172294	Applefort	Clare	Shannon	Managed	Yes	1	1	1	0	1
10L427	185799	210837	Shanbally	Galway	Gurteen	Unmanaged		0	1	1	0	1
10L428	193475	209436	Boolinderry	Tipperary	Gurteen	Managed		0	1	1	0	1
								2	14	14	0	14

Automated Passive Monitoring Sites 220 kV line

*Sites coloured red denote hedgerow with a gap ≥10 meters

AUTOMATED PASSIVE MONITORING

SITE PHOTOGRAPHS

10L116 Tirfinnog, Co. Monaghan Unmanaged

10L117 Liscarnan, Co. Monaghan ≥10m Unmanaged

10L118 Silloge, Co. Meath Managed

10L119 Randalstown, Co. Meath Unmanaged

10L120 Laheen south, Co. Leitrim Unmanaged

10L121 Belmont, Co. Galway ≥10m Managed

10L122 Cloone, Co. Leitrim Managed

10L123 Kilfeilim, Co. Galway 1km LHS Managed

10L124 Ballymacloon, Co. Glare 1km LHS Managed

10L125 Ballyroe, Co. Clare 1km LHS Managed

10L126 Coolrattin, Co. Waterford Managed

10L127 Clonsilla, Co. Wexford ≥10m Unmanaged

10L128 Ballyrahan, Co. Wexford ≥10m Unmanaged

10L216 Cloghreagh, Co. Meath Unmanaged

10L217 Craigs, Co. Meath Unmanaged

10L218 Rosdoowaun, Co. Leitrim Unmanaged

10L219 Kilamaun, Co. Leitrim Managed

10L220 Cloonfinna, Co. Leitrim Unmanaged

10L221 Rinn, Co. Galway ≥10m 1km LHS Managed

10L222 Ballymore, Co. Galway 1km LHS Unmanaged

10L223 Gortaboy, Co. Galway Unmanaged

10L224 Curraghmore, Co. Tipperary Unmanaged

10L225 Lissahane, Co. Waterford Managed

10L226 Cullenagh, Co. Waterford Managed

10L227 Cunaberry, Co. Wexford Managed

10L228 Drisoge, Co. Wexford Managed

10L229 Craans, Co. Carlow Managed

10L415 Carheeny Beg, Co. Galway Managed

10L416 Ballygeagin, Co. Galway 1km LHS Unmanaged

10L417 Knockatermin, Co. Clare 1km LHS Unmanaged

10L418 Kilcorban, Co. Galway Managed

10L419 Oldstreet, Co. Galway Managed

10L420 Cappagh, Co. Galway Unmanaged

10L421 Rathluby, Co. Clare ≥10m Unmanaged

10L422 Shandangan, Co. Clare 1km LHS Managed

10L423 Knockaderreen, Co. Clare Managed

10L424 Ballyea North, Co. Tipperary Unmanaged

10L425 Crean, Co. Clare Unmanaged

10L426 Applefort, Co. Clare 1km LHS Managed

10L427 Shanbally, Co. Galway Unmanaged

10L428 Boolinderry, Co. Tipperary Managed

WEATHER DATA

PASSIVE MONITORING

A 7 day weather summary is compiled for each individual Passive Monitoring Site. Data is taken from daily weather records at the weather stations (manual or automated) located nearest each individual site.

Source: Met Eireann Website – ‘Past Weather’

Site	Date	Rainfall (mm)	Max Temp (ºC)	Min Temp (ºC)	Grass Min Temp (ºC)	Mean Windspeed (knots)	Gusts (if >=34 knots)	Sunshine (hours)
	Mt. Dillon, Co. Roscommon							
10L122	**16/07/2012**	**6.4**	**19**	**12.6**	**12.3**	**5.5**		
	17/07/2012	**13.3**	**17.1**	**13.2**	**12.9**	**7.8**		
	18/07/2012	**4.1**	**19.1**	**10.5**	**9.1**	**7.2**		
	19/07/2012	**0.1**	**15.7**	**9.3**	**7.8**	**6.7**		
	20/07/2012	**0**	**17.5**	**6.8**	**4.8**	**4.9**		
	21/07/2012	**0**	**19.7**	**5.6**	**4.6**	**3.8**		
	22/07/2012	**3.6**	**20.8**	**13.5**	**12.7**	**9.9**		
	Shannon, Co. Limerick*							
10L123	**17/08/2012**	**3.1**	**21.4**	**13.4**	**14.6**	**6.8**		**5.5**
	18/08/2012	**0**	**21.8**	**13**	**12.4**	**11.1**		**11.1**
	19/08/2012	**0.3**	**21.1**	**15.6**	**15.2**	**12.7**		**4.6**
	20/08/2012	**0.1**	**20.8**	**15.1**	**15.2**	**8.6**		**9.3**
	21/08/2012	**2.9**	**18.4**	**14.3**	**14.3**	**12.7**		**9.2**
	22/08/2012	**9.3**	**18.5**	**13.8**	**13.6**	**12.6**		**9.2**
	23/08/2012	**0.5**	**17.4**	**13.1**	**13.2**	**8.4**		**0**
10L124	**17/08/2012**	**3.1**	**21.4**	**13.4**	**14.6**	**6.8**		**5.5**
	18/08/2012	**0**	**21.8**	**13**	**12.4**	**11.1**		**11.1**
	19/08/2012	**0.3**	**21.1**	**15.6**	**15.2**	**12.7**		**4.6**
	20/08/2012	**0.1**	**20.8**	**15.1**	**15.2**	**8.6**		**9.3**
	21/08/2012	**2.9**	**18.4**	**14.3**	**14.3**	**12.7**		**9.2**
	22/08/2012	**9.3**	**18.5**	**13.8**	**13.6**	**12.6**		**9.2**
	23/08/2012	**0.5**	**17.4**	**13.1**	**13.2**	**8.4**		**0**

* Shannon Airport is a manually operated weather station and includes sunshine hours. All other stations are automatic.

Site	Date	Rainfall (mm)	Max Temp (ºC)	Min Temp (ºC)	Grass Min Temp (ºC)	Mean Windspeed (knots)	Gusts (if >=34 knots)	Sunshine (hours)
10L125	**31/08/2012**	**0**	**17.7**	**11.1**	**11.2**	**8.5**		**0.7**
	01/09/2012	**1.8**	**19**	**13.1**	**9.4**	**11.8**		**4.3**
	02/09/2012	**0.1**	**17.4**	**12**	**7.9**	**5.5**		**0.2**
	03/09/2012	**0.9**	**21.1**	**9.9**	**6.6**	**7.5**		**3.8**
	04/09/2012	**0.1**	**18**	**9.4**	**6.3**	**7.4**		**8.4**
	05/09/2012	**0**	**18.6**	**6.6**	**3.4**	**2.6**		**10.3**
	06/09/2012	**0**	**19.4**	**9.6**	**4.9**	**7.8**		**11.3**
	Moorepark, Co Cork							
10L126	**07/09/2012**	**0**	**20.1**	**8.2**	**6.8**	**2**		
	08/09/2012	**0**	**17.2**	**12.4**	**11.1**	**4.5**		
	09/09/2012	**0.7**	**19.6**	**12.9**	**12**	**6.3**		
	10/09/2012	**2.7**	**17.5**	**8.4**	**6.4**	**4.5**		
	11/09/2012	**2.4**	**13.9**	**8.2**	**6.9**	**6.5**		
	12/09/2012	**0.6**	**17.8**	**8.2**	**6.5**	**5.3**		
	13/09/2012	**0**	**19.6**	**7.2**	**4.8**	**5.3**		
	Oak Park, Co. Carlow							
10L127	**14/09/2012**	**0.1**	**18**	**10.4**	**5.8**	**9.6**		
	15/09/2012	**0.1**	**16.4**	**11.2**	**9.2**	**6.1**		
	16/09/2012	**2.2**	**17.5**	**8.7**	**5.1**	**8.8**		
	17/09/2012	**0.9**	**15.3**	**8.2**	**5.4**	**9.3**		
	18/09/2012	**1.8**	**14.5**	**7.1**	**3.1**	**8.7**		
	19/09/2012	**0**	**15.5**	**5.2**	**0.6**	**5.6**		
	20/09/2012	**0.1**	**15.8**	**9.7**	**5.9**	**6.3**		

Site	Date	Rainfall (mm)	Max Temp (ºC)	Min Temp (ºC)	Grass Min Temp (ºC)	Mean Windspeed (knots)	Gusts (if >=34 knots)	Sunshine (hours)
10L128	**21/09/2012**	**3.1**	**14.6**	**3.1**	**-1.9**	**5.5**		
	22/09/2012	**0**	**14**	**2**	**-2.5**	**2.8**		
	23/09/2012	**0**	**14.4**	**2.2**	**-1.5**	**3**		
	24/09/2012	**4.7**	**10**	**7.6**	**7.2**	**7.3**		
	25/09/2012	**12.8**	**10.8**	**8.3**	**8**	**8.8**		
	26/09/2012	**2.2**	**15.2**	**8.6**	**6.2**	**11.7**		
	27/09/2012	**0.5**	**13.7**	**8.3**	**6.4**	**6.7**		

* Shannon Airport is a manually operated weather station and includes sunshine hours. All other stations are automatic.

Site	Date	Rainfall (mm)	Max Temp (ºC)	Min Temp (ºC)	Grass Min Temp (ºC)	Mean Windspeed (knots)	Gusts (if >=34 knots)	Sunshine (hours)
	Ballyhaise, Co. Cavan							
10L216	21/06/2012	5.6	13.5	10.2	9.8	5		
	22/06/2012	3.5	14.5	10.4	9.4	10.6		
	23/06/2012	2.3	15.2	10.3	9	8.6		
	24/06/2012	0.4	17.4	9.4	4.9	5.4		
	25/06/2012	0	17.9	8.9	5.1	3		
	26/06/2012	6	19.6	10.5	9.1	6.1		
	27/06/2012	7.8	22.1	14.8	14.5	5.7		
	Dunsanny, Co. Meath							
10L217	02/07/2012	8.9	19.4	13.4	13.2	5.1		
	03/07/2012	1.5	16.6	12.8	14.4	6		
	04/07/2012	5.7	18.2	11.9	12.9	4.5		
	05/07/2012	1.5	19.6	10.6	10.9	3.4		
	06/07/2012	12.9	17.4	9.4	11.1	5.8		
	07/07/2012	1.1	19.2	12.6	13.7	8.2		
	08/07/2012	2.3	13.8	10.5	13.4	5.5		
	Mt. Dillon, Co. Roscommon							
10L218	09/07/2012	2.3	16.7	10.1	9.4	7.5		
	10/07/2012	0.6	17.3	9.5	8.4	8.5		
	11/07/2012	4.7	15.6	7.5	4.7	6.8		
	12/07/2012	0.2	17.3	5.5	4	6		
	13/07/2012	0.1	18.8	9.9	10.1	5.7		
	14/07/2012	0.1	15.7	7.8	5.4	7		
	15/07/2012	0	18.7	5.4	3.3	6.6		

Site	Date	Rainfall (mm)	Max Temp (ºC)	Min Temp (ºC)	Grass Min Temp (ºC)	Mean Windspeed (knots)	Gusts (if >=34 knots)	Sunshine (hours)
10L219	**09/07/2012**	**2.3**	**16.7**	**10.1**	**9.4**	**7.5**		
	10/07/2012	**0.6**	**17.3**	**9.5**	**8.4**	**8.5**		
	11/07/2012	**4.7**	**15.6**	**7.5**	**4.7**	**6.8**		
	12/07/2012	**0.2**	**17.3**	**5.5**	**4**	**6**		
	13/07/2012	**0.1**	**18.8**	**9.9**	**10.1**	**5.7**		
	14/07/2012	**0.1**	**15.7**	**7.8**	**5.4**	**7**		
	15/07/2012	**0**	**18.7**	**5.4**	**3.3**	**6.6**		
10L220	**09/07/2012**	**2.3**	**16.7**	**10.1**	**9.4**	**7.5**		
	10/07/2012	**0.6**	**17.3**	**9.5**	**8.4**	**8.5**		
	11/07/2012	**4.7**	**15.6**	**7.5**	**4.7**	**6.8**		
	12/07/2012	**0.2**	**17.3**	**5.5**	**4**	**6**		
	13/07/2012	**0.1**	**18.8**	**9.9**	**10.1**	**5.7**		
	14/07/2012	**0.1**	**15.7**	**7.8**	**5.4**	**7**		
	15/07/2012	**0**	**18.7**	**5.4**	**3.3**	**6.6**		
	Mace Head, Co. Galway							
10L221	**24/072012**	**7.9**	**15.5**	**12**	**8.4**	**4.3**		
	25/07/2012	**0.2**	**18.3**	**9.7**	**5.8**	**6.5**		
	26/07/2012	**1**	**16.7**	**11.5**	**8.3**	**9.3**		
	27/07/2012	**0**	**16.3**	**12.2**	**10.5**	**16.6**		
	28/07/2012	**2.6**	**15.6**	**10.9**	**9.8**	**17.2**		
	29/07/2012	**0.8**	**15.2**	**10.2**	**8.2**	**13.7**		
	30/07/2012	**0.8**	**17**	**10.9**	**9.4**	**7**		

Site	Date	Rainfall (mm)	Max Temp (ºC)	Min Temp (ºC)	Grass Min Temp (ºC)	Mean Windspeed (knots)	Gusts (if >=34 knots)	Sunshine (hours)
10L222	**24/072012**	**7.9**	**15.5**	**12**	**8.4**	**4.3**		
	25/07/2012	**0.2**	**18.3**	**9.7**	**5.8**	**6.5**		
	26/07/2012	**1**	**16.7**	**11.5**	**8.3**	**9.3**		
	27/07/2012	**0**	**16.3**	**12.2**	**10.5**	**16.6**		
	28/07/2012	**2.6**	**15.6**	**10.9**	**9.8**	**17.2**		
	29/07/2012	**0.8**	**15.2**	**10.2**	**8.2**	**13.7**		
	30/07/2012	**0.8**	**17**	**10.9**	**9.4**	**7**		
10L223	**24/07/2012**	**7.9**	**15.5**	**12**	**8.4**	**4.3**		
	25/07/2012	**0.2**	**18.3**	**9.7**	**5.8**	**6.5**		
	26/07/2012	**1**	**16.7**	**11.5**	**8.3**	**9.3**		
	27/07/2012	**0**	**16.3**	**12.2**	**10.5**	**16.6**		
	28/07/2012	**2.6**	**15.6**	**10.9**	**9.8**	**17.2**		
	29/07/2012	**0.8**	**15.2**	**10.2**	**8.2**	**13.7**		
	30/07/2012	**0.8**	**17**	**10.9**	**9.4**	**7**		
	Gurteen College, Co. Tipperary							
10L224	**25/08/2012**	**0.7**	**18.9**	**12.3**	**11.2**	**8**		
	26/08/2012	**2.3**	**17.2**	**7.9**	**6.2**	**8.4**		
	27/08/2012	**3.5**	**18.8**	**11.7**	**10.3**	**10.7**		
	28/08/2012	**4.3**	**18.1**	**10**	**8.4**	**11**		
	29/08/2012	**3.1**	**17**	**11.6**	**9.7**	**10.7**		
	30/08/2012	**0**	**16.4**	**7.4**	**4.1**	**8.3**		
	31/08/2012	**0.1**	**18.2**	**7.3**	**4.8**	**8.2**		

Site	Date	Rainfall (mm)	Max Temp (ºC)	Min Temp (ºC)	Grass Min Temp (ºC)	Mean Windspeed (knots)	Gusts (if >=34 knots)	Sunshine (hours)
	Moorepark, Co Cork							
10L225	**07/09/2012**	**0**	**20.1**	**8.2**	**6.8**	**2**		
	08/09/2012	**0**	**17.2**	**12.4**	**11.1**	**4.5**		
	09/09/2012	**0.7**	**19.6**	**12.9**	**12**	**6.3**		
	10/09/2012	**2.7**	**17.5**	**8.4**	**6.4**	**4.5**		
	11/09/2012	**2.4**	**13.9**	**8.2**	**6.9**	**6.5**		
	12/09/2012	**0.6**	**17.8**	**8.2**	**6.5**	**5.3**		
	13/09/2012	**0**	**19.6**	**7.2**	**4.8**	**5.3**		
10L226	**07/09/2012**	**0**	**20.1**	**8.2**	**6.8**	**2**		
	08/09/2012	**0**	**17.2**	**12.4**	**11.1**	**4.5**		
	09/09/2012	**0.7**	**19.6**	**12.9**	**12**	**6.3**		
	10/09/2012	**2.7**	**17.5**	**8.4**	**6.4**	**4.5**		
	11/09/2012	**2.4**	**13.9**	**8.2**	**6.9**	**6.5**		
	12/09/2012	**0.6**	**17.8**	**8.2**	**6.5**	**5.3**		
	13/09/2012	**0**	**19.6**	**7.2**	**4.8**	**5.3**		
	Oak Park, Co. Carlow							
10L227	**14/09/2012**	**0.1**	**18**	**10.4**	**5.8**	**9.6**		
	15/09/2012	**0.1**	**16.4**	**11.2**	**9.2**	**6.1**		
	16/09/2012	**2.2**	**17.5**	**8.7**	**5.1**	**8.8**		
	17/09/2012	**0.9**	**15.3**	**8.2**	**5.4**	**9.3**		
	18/09/2012	**1.8**	**14.5**	**7.1**	**3.1**	**8.7**		
	19/09/2012	**0**	**15.5**	**5.2**	**0.6**	**5.6**		
	20/09/2012	**0.1**	**15.8**	**9.7**	**5.9**	**6.3**		

Site	Date	Rainfall (mm)	Max Temp (ºC)	Min Temp (ºC)	Grass Min Temp (ºC)	Mean Windspeed (knots)	Gusts (if >=34 knots)	Sunshine (hours)
10L228	14/09/2012	0.1	18	10.4	5.8	9.6		
	15/09/2012	0.1	16.4	11.2	9.2	6.1		
	16/09/2012	2.2	17.5	8.7	5.1	8.8		
	17/09/2012	0.9	15.3	8.2	5.4	9.3		
	18/09/2012	1.8	14.5	7.1	3.1	8.7		
	19/09/2012	0	15.5	5.2	0.6	5.6		
	20/09/2012	0.1	15.8	9.7	5.9	6.3		
10L229	21/09/2012	3.1	14.6	3.1	-1.9	5.5		
	22/09/2012	0	14	2	-2.5	2.8		
	23/09/2012	0	14.4	2.2	-1.5	3		
	24/09/2012	4.7	10	7.6	7.2	7.3		
	25/09/2012	12.8	10.8	8.3	8	8.8		
	26/09/2012	2.2	15.2	8.6	6.2	11.7		
	27/09/2012	0.5	13.7	8.3	6.4	6.7		

Site	Date	Rainfall (mm)	Max Temp (ºC)	Min Temp (ºC)	Grass Min Temp (ºC)	Mean Windspeed (knots)	Gusts (if >=34 knots)	Sunshine (hours)
	Shannon, Co. Limerick*							
10L415	**01/08/2012**	**0.5**	**17.9**	**12.4**	**10.4**	**13.5**		**6.4**
	02/08/2012	**0.3**	**18.3**	**12.1**	**9.7**	**12**		**2.8**
	03/08/2012	**3.2**	**17.1**	**13.3**	**11.1**	**10.8**		**3.4**
	04/08/2012	**2.4**	**19.8**	**13**	**13.1**	**9.4**		**7.1**
	05/08/2012	**0.3**	**16.1**	**11.7**	**11.8**	**6.9**		**0**
	06/08/2012	**0.8**	**16.3**	**9.1**	**7.5**	**7.3**		**0.4**
	07/08/2012	**0.5**	**19.6**	**12.6**	**16.9**	**5.8**		**1.4**
10L416	**01/08/2012**	**0.5**	**17.9**	**12.4**	**10.4**	**13.5**		**6.4**
	02/08/2012	**0.3**	**18.3**	**12.1**	**9.7**	**12**		**2.8**
	03/08/2012	**3.2**	**17.1**	**13.3**	**11.1**	**10.8**		**3.4**
	04/08/2012	**2.4**	**19.8**	**13**	**13.1**	**9.4**		**7.1**
	05/08/2012	**0.3**	**16.1**	**11.7**	**11.8**	**6.9**		**0**
	06/08/2012	**0.8**	**16.3**	**9.1**	**7.5**	**7.3**		**0.4**
	07/08/2012	**0.5**	**19.6**	**12.6**	**16.9**	**5.8**		**1.4**
10L417	**01/08/2012**	**0.5**	**17.9**	**12.4**	**10.4**	**13.5**		**6.4**
	02/08/2012	**0.3**	**18.3**	**12.1**	**9.7**	**12**		**2.8**
	03/08/2012	**3.2**	**17.1**	**13.3**	**11.1**	**10.8**		**3.4**
	04/08/2012	**2.4**	**19.8**	**13**	**13.1**	**9.4**		**7.1**
	05/08/2012	**0.3**	**16.1**	**11.7**	**11.8**	**6.9**		**0**
	06/08/2012	**0.8**	**16.3**	**9.1**	**7.5**	**7.3**		**0.4**
	07/08/2012	**0.5**	**19.6**	**12.6**	**16.9**	**5.8**		**1.4**

* Shannon Airport is a manually operated weather station and includes sunshine hours. All other stations are automatic.

Site	Date	Rainfall (mm)	Max Temp (ºC)	Min Temp (ºC)	Grass Min Temp (ºC)	Mean Windspeed (knots)	Gusts (if >=34 knots)	Sunshine (hours)
	Gurteen College, Co. Tipperary							
10L418	08/08/2012	0	21.6	13.9	10.8	2.7		
	09/08/2012	0	23.6	15.2	12.2	2.5		
	10/08/2012	0	24.7	13.2	9.5	6.5		
	11/08/2012	0	20.7	14	12.3	9.3		
	12/08/2012	9.7	21.2	14.8	13.8	8.4		
	13/08/2012	7.4	21.2	13.8	12.3	8.8		
	14/08/2012	0	21.5	13.8	12.2	8.4		
10L419	08/08/2012	0	21.6	13.9	10.8	2.7		
	09/08/2012	0	23.6	15.2	12.2	2.5		
	10/08/2012	0	24.7	13.2	9.5	6.5		
	11/08/2012	0	20.7	14	12.3	9.3		
	12/08/2012	9.7	21.2	14.8	13.8	8.4		
	13/08/2012	7.4	21.2	13.8	12.3	8.8		
	14/08/2012	0	21.5	13.8	12.2	8.4		
10L420	08/08/2012	0	21.6	13.9	10.8	2.7		
	09/08/2012	0	23.6	15.2	12.2	2.5		
	10/08/2012	0	24.7	13.2	9.5	6.5		
	11/08/2012	0	20.7	14	12.3	9.3		
	12/08/2012	9.7	21.2	14.8	13.8	8.4		
	13/08/2012	7.4	21.2	13.8	12.3	8.8		
	14/08/2012	0	21.5	13.8	12.2	8.4		

Site	Date	Rainfall (mm)	Max Temp (ºC)	Min Temp (ºC)	Grass Min Temp (ºC)	Mean Windspeed (knots)	Gusts (if >=34 knots)	Sunshine (hours)
	Shannon, Co. Limerick*							
10L421	**17/08/2012**	**3.1**	**21.4**	**13.4**	**14.6**	**6.8**		**5.5**
	18/08/2012	**0**	**21.8**	**13**	**12.4**	**11.1**		**11.1**
	19/08/2012	**0.3**	**21.1**	**15.6**	**15.2**	**12.7**		**4.6**
	20/08/2012	**0.1**	**20.8**	**15.1**	**15.2**	**8.6**		**9.3**
	21/08/2012	**2.9**	**18.4**	**14.3**	**14.3**	**12.7**		**9.2**
	22/08/2012	**9.3**	**18.5**	**13.8**	**13.6**	**12.6**		**9.2**
	23/08/2012	**0.5**	**17.4**	**13.1**	**13.2**	**8.4**		**0**
10L422	**24/08/2012**	**17.1**	**16.4**	**13**	**13.6**	**10**		**0**
	25/08/2012	**0.5**	**18.5**	**11.4**	**10.3**	**9.8**		**8**
	26/08/2012	**1.7**	**17.8**	**8.8**	**8.2**	**10.3**		**4.3**
	27/08/2012	**0.2**	**19.1**	**13.6**	**12.9**	**12.5**		**6.5**
	28/08/2012	**2.2**	**19.2**	**12.3**	**11.5**	**13.1**		**3.1**
	29/08/2012	**2.3**	**17.1**	**12.6**	**11.7**	**13.5**		**4.2**
	30/08/2012	**0**	**17.1**	**10.6**	**10**	**9.3**		**9.9**
10L423	**24/08/2012**	**17.1**	**16.4**	**13**	**13.6**	**10**		**0**
	25/08/2012	**0.5**	**18.5**	**11.4**	**10.3**	**9.8**		**8**
	26/08/2012	**1.7**	**17.8**	**8.8**	**8.2**	**10.3**		**4.3**
	27/08/2012	**0.2**	**19.1**	**13.6**	**12.9**	**12.5**		**6.5**
	28/08/2012	**2.2**	**19.2**	**12.3**	**11.5**	**13.1**		**3.1**
	29/08/2012	**2.3**	**17.1**	**12.6**	**11.7**	**13.5**		**4.2**
	30/08/2012	**0**	**17.1**	**10.6**	**10**	**9.3**		**9.9**

* Shannon Airport is a manually operated weather station and includes sunshine hours. All other stations are automatic.

Site	Date	Rainfall (mm)	Max Temp (ºC)	Min Temp (ºC)	Grass Min Temp (ºC)	Mean Windspeed (knots)	Gusts (if >=34 knots)	Sunshine (hours)
10L424	24/08/2012	17.1	16.4	13	13.6	10		0
	25/08/2012	0.5	18.5	11.4	10.3	9.8		8
	26/08/2012	1.7	17.8	8.8	8.2	10.3		4.3
	27/08/2012	0.2	19.1	13.6	12.9	12.5		6.5
	28/08/2012	2.2	19.2	12.3	11.5	13.1		3.1
	29/08/2012	2.3	17.1	12.6	11.7	13.5		4.2
	30/08/2012	0	17.1	10.6	10	9.3		9.9
10L425	31/08/2012	0	17.7	11.1	11.2	8.5		0.7
	01/09/2012	1.8	19	13.1	9.4	11.8		4.3
	02/09/2012	0.1	17.4	12	7.9	5.5		0.2
	03/09/2012	0.9	21.1	9.9	6.6	7.5		3.8
	04/09/2012	0.1	18	9.4	6.3	7.4		8.4
	05/09/2012	0	18.6	6.6	3.4	2.6		10.3
	06/09/2012	0	19.4	9.6	4.9	7.8		11.3
10L426	31/08/2012	0	17.7	11.1	11.2	8.5		0.7
	01/09/2012	1.8	19	13.1	9.4	11.8		4.3
	02/09/2012	0.1	17.4	12	7.9	5.5		0.2
	03/09/2012	0.9	21.1	9.9	6.6	7.5		3.8
	04/09/2012	0.1	18	9.4	6.3	7.4		8.4
	05/09/2012	0	18.6	6.6	3.4	2.6		10.3
	06/09/2012	0	19.4	9.6	4.9	7.8		11.3

* Shannon Airport is a manually operated weather station and includes sunshine hours. All other stations are automatic.

Site	Date	Rainfall (mm)	Max Temp (ºC)	Min Temp (ºC)	Grass Min Temp (ºC)	Mean Windspeed (knots)	Gusts (if >=34 knots)	Sunshine (hours)
	Gurteen College, Co. Tipperary							
10L427	**01/09/2012**	**0.3**	**18.7**	**12.2**	**10.8**	**9.7**		
	02/09/2012	**0.3**	**18.4**	**10.4**	**7.8**	**5.2**		
	03/09/2012	**0.2**	**21.3**	**8.9**	**6**	**7.2**		
	04/09/2012	**0.1**	**19**	**8.4**	**4.6**	**6.9**		
	05/09/2012	**0.1**	**18.1**	**5.5**	**2.6**	**2.8**		
	06/09/2012	**0**	**19.7**	**7.7**	**3.9**	**8.4**		
	07/09/2012	**1.1**	**19.1**	**12.8**	**11.5**	**6.1**		
10L427	**21/09/2012**	**6.8**	**13.5**	**4.2**	**-1.6**	**5.5**		
	22/09/2012	**0**	**14**	**2.9**	**-2**	**5.6**		
	23/09/2012	**0**	**14.8**	**5.1**	**0.5**	**7**		
	24/09/2012	**3.9**	**10.3**	**4.9**	**1**	**6.1**		
	25/09/2012	**7.6**	**10.9**	**7.9**	**7.6**	**9.7**		
	26/09/2012	**0.1**	**15.3**	**7.3**	**5.1**	**12.5**		
	27/09/2012	**0.8**	**13.7**	**8**	**6.7**	**7.5**		