EirGrid Evidence Based Environmental Studies Study 5: Birds

Literature review and evidence based field study on the effects of high voltage transmission lines on birds

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SUMMARY

Wild birds and their habitats are an important part of the natural environment. Over 450 birds have been recorded in Ireland. Ireland is important for migrating birds with large numbers of birds such as waterfowl and waders spending the winter in Ireland. Summer migrants such as swallows and terns are also a feature of Ireland’s bird life.

This report is an independent, evidence-based study undertaken by experts in bird ecology. The research examines the effects of existing high voltage transmission projects at a number of sites on bird activity and behaviour.

The purpose of this study has been:

- To determine the effects of existing high voltage transmission infrastructure on bird activity in Ireland

- To provide a factual basis for the development of bird specific recommendations and guidelines for electricity transmission projects

The routing of transmission projects is a complex process. It requires a balance between a number of issues, including EirGrid’s obligations to ensure a safe and secure transmission grid, land use constraints, cost, engineering and other technical requirements. Impacts on the natural environment must also be considered. Transmission lines have the potential to impact on birds and routing of new lines must take this into account.

This study included a literature review of existing information and a field survey at sites around Ireland. The aim of the study is to find out if, and how, transmission powerlines affect birds in Ireland.

Published information from around the world has shown that certain birds are more at risk of collision with transmission lines than others. Large species such as swans, geese, and cranes are most at risk. Bird species considered ‘poor fliers’ such as grouse, pheasant, and rails are also at risk of collision. Certain factors such as time

spent in flight, territorial displays, foraging flights or night flights can increase collision risk for birds including waders and raptors where overhead lines are present. Local conditions such as landscape and weather conditions can also influence the risk of collision.

The thin wire at the top of powerlines[1] is widely reported as the main cause of bird collisions. Collisions with powerlines are considered to be rare events. Most studies conclude that mortality from collisions is unlikely to affect bird populations. However, where rare or protected species occur, impacts could be significant.

Measures to reduce bird collisions include careful line route assessments and the marking of lines to make them more visible to birds. Research shows positive results from marking lines, with reductions in bird deaths of 50% or more. The location for marked sections of transmission line is determined by survey and analysis of bird movements. Monitoring the effectiveness of the line marking is recommended.

The risk of electrocution on the transmission system is low. This is due to the wide spacing between live elements on the transmission lines and support structures.

The possible impacts of transmission line construction and electromagnetic fields (EMFs) are also investigated. Construction activities may cause temporary disturbance or permanent displacement to birds.

An important part of this study included a survey of collision risk. This involved a widespread field study in 2012/2013. This study examined a number of high risk sites (5) for birds, and a sample of low risk (54) or control sites on the existing transmission system. Searches for dead birds were carried out at all sites.

A targeted survey was undertaken in 2014 at three high risk sites. This survey also collected information on flight activity of target species. Target species included swans, geese, ducks, gulls, herons, raptors, waders, and cormorant.

[1] Commonly referred to as the earth wire

Results of the surveys were broadly in line with collision estimates published in the scientific literature. Results from high risk sites showed estimated collision rates of 0 to 179 birds per kilometre per year. This result does not take account of possible bias such as scavenger removal of dead birds by fox for example. The species recorded most frequently as collision victims at high and low risk sites included crow and pigeon species. Small numbers of gulls, waders, ducks, and passerines were also recorded. Grey Heron was recorded at wetland sites.

The flight activity survey provided new information on bird responses to transmission lines. No collisions were observed, however some avoidance behaviour was noted. At all sites, the majority of birds flew above the powerlines. The exception was at the 400 kV site (with the tallest pylons), where a third of all birds flew beneath the wires. Very few birds crossed powerlines at or near to pylons.

This study provides data and results which will inform the development of bird specific recommendations and guidelines for transmission projects in Ireland. The preparation of guidelines will ensure a consistent approach to ecology, including birds, at all stages of the development of transmission projects.

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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 if there are effects from the construction and operation of existing high voltage electricity transmission infrastructure on bird activity in Ireland. To do this a literature review and bird survey were conducted.

The electricity network in Ireland comprises of both transmission and distribution line infrastructure[2]. Transmission infrastructure tends to be larger and higher from the ground, with multiple wires at different heights; distribution infrastructure tends to be smaller and lower, with wires often at the same height (Barrientos *et al.*, 2012).

For the purposes of this Evidence-Based Environmental Study, both transmission and distribution lines are referred to as powerlines. This is due to many of the factors discussed in relation to bird collisions applying equally to both transmission and distribution lines. In addition, it became evident whilst conducting the literature review that it is not always clear whether reports and findings relate to transmission or distribution lines.

The main focus of this study has been to examine the potential adverse effects of overhead power lines on birds in Ireland, including collision and electrocution, displacement resulting from avoidance or disturbance, disruption of local or migratory movements and displacement or disturbance due to habitat loss and fragmentation (Drewitt and Langston, 2008). Bird surveys have been conducted on sites determined as low risk collision sites and high risk collision sites; bird mortality searches and flight activity watches have been part of these surveys.

Any future development of the electricity network in Ireland will comply with existing EirGrid Ecology Guidelines and include any further measures recommended from the findings of this Evidence-Based Environmental Study.

1.3 THE TRANSMISSION NETWORK AND BIRDS

Electricity supply is an essential service for Ireland's society and economy. The transmission system is a meshed network of 400kV, 220kV and 110kV 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

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[2] Transmission lines transfer electricity at high voltage from power generating plants to substations; distribution lines transfer electricity at low voltage from substations to customers.

[3] Transmission Development Plan 2008-2012 EirGrid

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.

The Electricity Supply Board (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 coordinates 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.

Birds and all other animals and plants in Ireland, are an ecological resource. EirGrid is committed to the preservation of this resource and ensuring that transmission infrastructure development is undertaken in an environmentally sensitive manner that conserves it. EirGrid already comply with Ecology Guidelines[5] during the construction phase of projects, and where applicable the findings of this Evidence-Based Environmental Study will be integrated with the existing Ecology Guidelines.

The potential effects of transmission infrastructure development on bird ecology relate primarily to the potential for temporary and/or permanent habitat disturbance/loss and/or fragmentation during the construction stage. This may lead to the damage or destruction of roosting and/or nesting sites, as well as foraging habitat. The routing of an overhead transmission line could continue to affect birds after construction, by obstructing foraging and/or transit flightpaths that may be used on a daily basis or as part of a traditional migratory route.

In transmission infrastructure development, every effort is made to cause least disturbance to landowners and local residents during construction. However it is also necessary to ensure that the preferred route does not adversely impact birds. This includes their nesting and roosting sites, foraging areas and transit routes, and applies equally to both known and previously unknown features. Irish wildlife legislation makes it an offence to hunt or injure a protected wild bird; or willfully take, remove, destroy, mutilate or disturb the eggs, nest, adults or unflown young of a protected wild bird.[6]

The significance of any adverse effects on birds depends on the location and scale of the proposed infrastructure and potential for screening and mitigation measures. This is why transmission

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[4] Statutory Instrument 445 (2000), entitled European Communities (Internal Market in Electricity Regulations, 2000)

[5] Flynn, M. & Nairn, R. (2012): Ecology Guidelines for Electricity Transmission Projects. EirGrid, Dublin

[6] The Wildlife Act 1976 and The Wildlife (Amendment) Act 2000

infrastructure development should be reviewed by a suitably qualified ecologist or ornithologist as the design of a scheme progresses.

1.4 STUDY LAYOUT

This Evidence-Based Environmental Study details two separate bodies of work, which are:

- a literature review on overhead power lines and the effects on bird populations, and
- the results of specifically commissioned field studies of bird mortality and flight activity in relation to high voltage transmission lines at a number of sites in Ireland.

Chapter 2 is the literature review and examines the issues of bird collision with overhead powerlines and bird electrocution. Morphology, environmental factors such as habitat and powerline design are all considered. Species collision rates, population effects, biases in surveys and mitigation are also reviewed.

Chapter 3 concludes the literature review and examines the potential issue of displacement of birds from locations beneath or close to overhead powerlines. There is limited information on this, so studies related to windfarms are referred to. Exposure to electric and magnetic fields (EMFs) during the operational phase is also reviewed.

Chapters 4 and 5 describe the field studies (2012-2014) of bird mortality at transmission powerline sites in Ireland. These studies were designed to help establish the impacts of transmission powerlines on birds by surveying chosen sections of transmission powerlines.

Chapter 4 outlines the field study conducted in 2012/2013, at both high collision and low collision risk sites. The species composition of birds found at both sites is presented and estimates of bird collisions at the high risk sites are also presented.

Chapter 5 outlines the intensive field study conducted in 2014 on a small number of sites with large populations of potentially vulnerable species. Flight activity surveys alongside bird mortality searches are detailed. The flight activity surveys recorded species numbers and bird behaviour, on approach to (and crossing) transmission powerlines.

The study concludes with a discussion of the 2014 crossing and collision rates, with comparability between surveys and published results.

2 LITERATURE REVIEW: COLLISION AND ELECTROCUTION OF BIRDS

2.1 INTRODUCTION

The literature review reported in chapters 2 and 3 of this report draws from studies carried out across a wide range of countries. It encompasses papers published in peer reviewed scientific journals in English, as well as 'grey' literature (e.g. unpublished research reports). Papers and reports were identified through a combination of reference lists from known source material and web based searches based on key words (e.g. birds, power transmission lines, collisions, electrocution, mitigation, flight diverters) and including the use of google scholar. Studies published in foreign language journals, and 'grey' literature reports not available on the internet, were not included, except where the results of such research could be quoted from a secondary source which was considered to be reliable.

Mortality of birds related to power line infrastructure is a worldwide conservation issue. Despite extensive research, design development, and mitigation, numerous fatal incidents occur each year (Prinsen *et al.*, 2011a, Lehman et al., 2007, Sundar *et al.*, 2005). According to Jenkins *et al.* (2010), over 65 million kilometres of medium and high voltage power lines are currently in use around the world and this is forecast to increase by 5% each year.

While there is some generic knowledge of why and where avian collision mortality is most likely to occur, and the kinds of birds most likely to be affected, understanding of the scale of mortality and demographic consequences of power line collisions for birds is generally poor (Jenkins et al., 2010). Much anecdotal information is available, but there are relatively few robust quantitative studies. Inconsistencies in field methods mean that comparisons between studies and extrapolation of the results to other areas are problematic. Depending on the size of the grid and bird species present, up to 10,000 electrocutions and many hundreds of thousands of collisions are thought to occur per country per year in the African-Eurasian region (Prinsen *et al.*, 2011a).

There are many factors to consider when assessing the risk of bird electrocution and collision with overhead power lines, all of which interact; the number of birds using a particular area and characteristics of individual bird species are an important consideration, as are a wide range of environmental factors and the design of power transmission lines.

2.2 COLLISIONS

Extensive literature has been published demonstrating that overhead wires, including transmission power lines, pose a collision risk to flying birds. The issue has been studied in a number of different places, principally North America, Europe and South Africa. Studies have focused mainly on bird species considered to be at risk of collision, or areas where collision mortality is considered to be high and, for a given species, the factors determining the risk of collision (see Prinsen *et al.*, 2011a; Jenkins *et al.*, 2010; Dewitt and Langston, 2006; Bevanger, 1998 for reviews). These influencing factors, including the bird species (morphology and behaviour), environmental factors and the actual type and design of the power lines, are discussed below.

Despite this research effort, the population consequences of collision mortality for birds (i.e. whether this mortality can contribute to or cause population declines or even extinction) remain largely unknown. In terms of environmental impact assessment, the conservation status of the species is important in determining the degree of ecological significance of any mortality. In population terms, the life-history strategy of the species is important: whether a species is long-lived with a low reproductive rate (K selected, e.g. raptors) or short-lived with high reproductive rate, (r selected, e.g. small passerines - e.g. see Reznick *et al.*, 2002) and also the age and status of the individual birds involved, with mortality of breeding adults likely to cause the greatest population level impacts.

2.2.1 Characteristics of Birds That Influence Collision Risk

The vulnerability of a bird species to collision is a combination of the exposure to collision risk and the susceptibility of the species to collision. Exposure depends on the time spent flying, the conditions in which birds fly at vulnerable heights and the location of foraging, roosting and nesting areas, and of migratory flight paths, in relation to power lines (Prinsen *et al.*, 2011a).

2.2.1.1 Morphology

Biological factors influencing susceptibility to collision include the bird's visual field and acuity, size, weight, wing structure, age and experience. The visual field and acuity affect the bird’s ability to detect power lines, and its size, weight and wing structure affect the ability to take evasive action (Jenkins *et al.*, 2010; Bevanger, 1994; Drewit and Langston, 2008).

Species with high wing loading (ratio of body weight to wing area) and low aspect (broad wings) are considered to run a high risk of collisions with power lines (Bevanger, 1998). So-called 'poor flyers’ (Rayner, 1988) are characterised by rapid flight, and a combination of heavy body and small wings which restricts swift evasive reactions to unexpected obstacles. This includes grouse, pheasants, partridges, crakes and rails (Bevanger, 1998).

Janss (2000) compared the abundance of bird species in the vicinity of power lines in Spain with records of mortality from corpse searches and carried out a discriminant analysis to see if wing morphology and body measurements could explain variation in the susceptibility of different species to power line deaths from collision and electrocution. A discriminant model found (statistically) significant effects and identified three categories: species with a high risk of collision, those with a high risk of electrocution and a mixed group susceptible to both. The main difference between species at risk of collision and electrocution was wing loading, with high wing loading being associated with a greater collision risk. In the ‘mixed’ group, power line mortality (all species seemed to be at risk of collision and some of electrocution) appeared to be dependent on factors such as habitat use and exposure to power lines, and behaviour (including tendency to perch on power lines) of bird species, rather than their morphology. Thus morphology can to some extent predict bird species at risk of collision with power lines, but other factors are also important.

2.2.1.2 Vision

The detectability of power lines depends on the visibility of the wires and the visual field of birds. Martin and Shaw (2010) have reported that certain bird species known to be particularly vulnerable to collisions with power lines (bustards Otididae; cranes Gruidae, storks Ciconiidae and raptors Accipitridae), have blind spots in their frontal vision, which, for example, render a bird blind in the direction of travel when the head is pitched to look downward. In general for birds, eyes are placed on the sides of the head, high resolution occurs in the lateral fields of view, and frontal vision may be tuned for the detection of movement rather than detail, so even if birds are looking ahead, frontal vision may not be in high resolution (Martin, 2011). A lack of vision above the head may explain why some bird species collide with the ground or earth wire (which is usually above conducting wires) but avoid collision with the conductors below. Species, such as ducks, which have eyes adapted to underwater vision, may be slightly short-sighted in air and unable to detect small diameter wires at distance (APLIC, 2012).

2.2.1.3 Age

For some species, the risk of mortality in relation to collision with power lines is greater for inexperienced immature birds. For such species, it also follows that mortality rates are likely to be higher during the post-breeding period, when there are increased numbers of young birds and juveniles may be dispersing or migrating through unfamiliar habitats. Rose and Baillie (1992) analysed bird ringing data (recoveries of dead, ringed, birds with associated information on cause of death) for Britain and Ireland in relation to patterns of mortality related to overhead wires. They found that first year birds were more vulnerable to collisions with overhead wires than adults in only seven of 34 species tested. The species showing (statistically) significant variation with age were Grey Heron (*Ardea cinerea*), Mallard (*Anas platyrhynchos*), Curlew (*Numenius arquata*), Song Thrush (*Turdus philomelos*), Mute Swan (*Cygnus olor*) and Canada Goose (*Branta Canadensis*).

Age-specific changes in collisions with overhead lines appeared to result from the inexperience of young birds, although differences in dispersion of juveniles and adults and age-related variation in flying activity might also be involved. For example, Mute swans were most likely to collide with overhead wires during their first six months of life and then in their third year. Young swans dispersing from natal areas into non-breeding flocks may be susceptible to collisions due to inexperience; a peak of collisions in the third year of life may correspond with birds dispersing from non-breeding flocks in search of a breeding territory, which may take several years and involve movements over large areas (Rose and Baillie, 1992).

2.2.1.4 Health and Condition

Poor health may increase collision risk. In mute swans, elevated blood levels of lead has been associated with power line collision risk in Britain (Kelly and Kelly 2005), and birds with lower weight and heavier toxin loads were over-represented in collision victims in Sweden (Mathiasson, 1999).

2.2.1.5 Behaviour

The tendency of some bird species, such as waterfowl, pigeons and starlings, to fly in large flocks, may increase the chance of collision with power lines; the vision of birds at the back of a group may be obscured by individuals in the front and they may notice wires too late to avoid collision (Prinsen *et al.*, 2011a).

During some types of behaviour such as display flights, mobbing, or escape from predators, birds may be more liable to collision (Bevanger, 1994). For example, a Dutch study of collision risk in grassland habitats with high breeding wader abundance, found most collision victims in April, corresponding with the start of the breeding season when many species undertake territorial display flights (Koops, 1987 cited in Prinsen *et al.*, 2011a). Seasonal differences in the collision rates of grouse at power lines in Norway were attributed to variation in flight behaviour throughout the year (Bevanger and Brøseth, 2004). Collision rates peaked in the winter when grouse make short, often downhill, gliding flights between food patches, when weather and visibility may be poor. Collision rates were also high in spring when males make display flights with activity peaking at twilight. No grouse collision victims were found during summer when food is plentiful, and few found in autumn, when food resources are also abundant. Birds may tend to also stay within restricted areas. Anthropogenic disturbance flushing birds into power lines has been well documented as a contributing factor to collisions (APLIC, 2012 and references therein).

Flight height and time spent on the wing will affect collision risk. Species spending more time at potential collision height with power lines will be at increased risk. Exposure to the risk of collision may be potentially high in very aerial species because they spend so much time on the wing, but not if they tend to fly well above the height of power lines. Conversely, largely terrestrial species are much less exposed to collision risk because they spend so little time in flight, but their effective exposure will be increased if most flights occur at power line height. Migrating birds often fly at high altitudes and may face a lower collision risk than birds making regular flights between foraging and roosting / nesting areas. However weather conditions such as heavy precipitation, strong winds or fog may force migrants to fly at lower altitudes, especially at night; and migratory birds may be less familiar with a landscape and obstacles than local residents (Prinsen *et al.*, 2011a).

Where power lines cross areas where birds make regular commuting flights, collision risk may also be increased (Janss and Ferrer, 2000). Henderson et al. (2006) investigated the risk of collision with power lines for Common Terns in North Wales, at a site where birds passed power lines between a breeding colony and feeding areas. The mortality of terns in relation to power lines was very low but observations indicated that adults flew closer to wires during the nestling and fledging stages than during courtship and incubation. There was no evidence this was related to environmental conditions, and it was concluded that birds feeding young took ‘short cuts’ to reduce their journey time but at the risk of increasing their vulnerability to collision.

Birds that regularly fly at night or in twilight are generally considered at greater risk of collision with power lines than species that fly mostly during the day; this includes birds making commuting or foraging flights and birds migrating at night. Prinsen *et al.* (2011a) cite quantitative studies in Britain (Scott *et al*., 1972), Holland (Heijnis, 1980), Germany (Hoerschelmann *et al*., 1988) and North America (Murphy *et al.*, 2009), demonstrating that most collisions occurred at night.

Recording nocturnal flight collisions from searches for bird remains under power lines would require searches just before dusk and just after dawn on a given night to be certain that collisions took place during darkness, requiring intensive fieldwork. The North American study (Murphy *et al.*, 2009) involved the use of bird strike indicators which can be installed on wires and register collisions based on vibration. A study in the Florida Everglades used a combination of radar and night vision equipment to record birds crossing a 3.7 km section of transmission power line between late February and early July in one year (Deng and Frederick, 2001); no collisions were observed but the sampling period was short (118 hours). It has been predicted that collision frequency may increase with latitude as the light conditions deteriorate but no data are available to support this theory (Prinsen *et al*., 2011a; Bevanger, 1994).

2.2.1.6 Distribution and Population Density

The geographic areas inhabited by a bird species will affect exposure to power lines and thus collision risk. Birds occupying and or migrating through areas with higher densities of people are likely to encounter power lines more frequently. Variations in the extent of overlap with power lines are likely to result in different mortality rates for populations of the same species occupying different areas.

Few studies have investigated the abundance of birds in the vicinity of power lines in conjunction with collision estimates. In Norway, an intensive study of grouse collisions at power lines found a significant effect of an index of population size on the variation in collision rates between study sites (Bevanger and Brøseth, 2004).

2.2.2 Environmental Factors Influencing Collision Risk

2.2.2.1 Topography

Topographical features can influence the potential for bird collisions with power lines. Mountain ranges, river valleys, and coastlines, may act as important flight corridors for long-distance bird movements, or on shorter flight lines between foraging and roosting areas. Topographic relief patterns may affect the alignment of avian flight paths, particularly where they fly close to the ground, channelling them into valleys, over passes, along ridges and into depressions as they follow energetically expedient ways to travel cross-country. Such channelling can be critical in determining risk exposure for commuting birds in a landscape traversed by multiple power lines (Jenkins *et al.*, 2010; APLIC, 1994; Bevanger, 1994). Topographical features can also influence the visibility of power lines particularly on the crest of mountain ranges where the visibility of power lines coupled with low cloud or misty conditions often leads to reduced visibility (APLIC, 1994; Rollan *et al.*, 2010).

2.2.2.2 Weather

Poor weather conditions are one of the most frequently described factors affecting power line collisions (APLIC, 1994). Reduced visibility resulting from fog, mist or precipitation increases collision risk, and under these conditions birds may tend to lower their flight height which also contributes to increased risk (Prinsen *et al.*, 2011a). Strong winds and storms may cause birds to lose flight manoeuvrability and increase the risk of collision. Hence, collision risk increases in locations prone to experiencing such weather conditions. Thus many casualties seem to be related to reduced visibility (fog, mist, precipitation and/or dense cloud cover) or loss of flight control where birds flying in high-velocity winds are propelled into fully visible power lines (APLIC, 1994; Anderson, 1978). Most birds avoid flying in adverse weather conditions, but when they do take flight or encounter these conditions unexpectedly or unavoidably (e.g. on migration) collision risk is increased (Prinsen *et al.*, 2011a). For most birds, slow flight, even for short periods, is energetically costly or aerodynamically impossible; this means that they cannot readily slow down to adjust their rate of visual information gain (i.e. look around more carefully for obstacles) in conditions of reduced visibility (Martin, 2011). Gulls are often more active than other birds in stormy conditions and may be at increased risk of power line collision (Scott *et al.*, 1972).

2.2.2.3 Habitats

Habitat will affect the assemblage of bird species occupying an area and therefore the species exposed to collision risk. Increased numbers of collisions with power lines may be observed in areas which support concentrations of 'high risk' birds, for example at wetland areas supporting high densities of wintering and passage waterfowl.

Interactions between the presence of power lines and habitat can occur. The presence of trees forces birds to increase their flight height and positioning overhead wires just below canopy height may prevent collision. In Norway, Bevanger and Brøseth (2004) found a significant effect of tree height on the probability of grouse collisions with power lines. Areas of power lines where grouse collisions were recorded generally had lower trees than places along power lines with no recorded grouse collisions. A study of daily flight routes by Greater White-fronted Geese (*Anser albifrons*) in Japan found that there were a higher proportion of flights over power lines located in woodland than over rice fields, whilst in some cases geese took indirect flight routes to avoid crossing lines over rice fields (Shimada, 2001). The overhead cables rarely protruded beyond tree top levels and may have been perceived by the geese as less of a hazard than exposed cables over rice fields.

2.2.3 Power Line Design Characteristics That Influence Collision Risk

The placement and orientation of overhead power lines relative to bird flight lines is an important factor affecting collision risk. Power lines which cross migratory flight paths or regular daily commuting routes used by birds pose a higher risk than those running parallel to flight paths. At Dungeness on the south coast of England, frequent collision mortality was recorded at transmission power lines crossing the flight path of migratory birds heading out to sea, or making landfall at the coast (Scott *et al.*, 1972). Orientation in relation to local weather patterns can be a factor also. In the San Luis Valley, Colorado, the north-south orientation of lines increased collision risk for cranes and waterfowl because birds crossing them in an east or west direction were subject to prevailing westerly tail winds (Brown, 1993 cited in APLIC, 1994, 2012).

Structural aspects are important also, including the diameter of conductors and earth wires and the number and configuration of conductors (APLIC 2012). Although there are too few studies to draw conclusions, it is considered by researchers that minimising the vertical aspect of multiple transmission wires ('bunching' them in a horizontal plane) reduces the height of the collision risk zone for birds (APLIC, 2012).

If several power lines pass through the same area then clustering of lines (running them parallel and close to each other) may reduce the risk of bird collisions by confining wires to a smaller area and making them more visible. However in conditions of decreased visibility, clustered power lines may increase collision risk.

It is widely reported that collisions with the thinner earth (sometimes called ground, shield or static) wires located above conductors are more frequent, as birds trying to avoid the larger conductor wires fail to see the earth wires (APLIC, 2012: Prinsen *et al.*, 2011a; Jenkins *et al.*, 2010; Drewitt and Langston, 2008). This appears often to be based on eyewitness (anecdotal) accounts of bird collisions. Collisions with power lines are relatively rare events and intensive observations of flight activity are required to quantify the rate of collisions with different wires. Based on the search criteria used for the literature review (see 2.1 above), only a few studies have been found that provide such data. In North Dakota, 109 birds were seen flying into wires during observation periods at seven power line study sites, and of these 102 (93 %) collided with the earth wire (Faanes, 1987). In South Carolina, 34 collisions were observed at two power line study sites, of which 28 (82 %) involved the static wire (Savareno *et al.*, 1996). Further evidence for a higher collision risk for birds with earth wires is provided by studies which report reductions in collision frequency when the earth wire is removed (Brown et al. 1987, cited from Jenkins et al. 2010; Beaulaurier *et al.*, 1984; Beaulaurier, 1981; cited from Bevanger and Brøseth, 2001). In subalpine habitat in Norway, grouse collisions were cut by about 50% after experimental removal of the earth wire at a section of power line (Bevanger and Brøseth, 2001).

2.2.4 Empirical Evidence for Bird Species Subject to Power Line Collisions

This section summarises evidence in the scientific literature for collisions between power lines and different types of birds. Where possible a distinction between transmission and distribution lines is made, but this is not always reported consistently. A review of collision risk studies in the African-Eurasian region found that in Western Europe, substantial research has been carried out in agricultural areas and wetlands and the species groups most frequently found dead under power lines were ducks and swans, waders, rails, gulls, pigeons and passerines (mostly starling and thrushes). In Northern Europe most of the available information is from low alpine birch forests in Norway, (which hold a markedly different avifauna to agricultural areas and wetlands), where grouse were the most frequent victims of collisions with power lines (Prinsen *et al.*, 2011a).

It has been reported that raptors and owls are not generally prone to collision with power lines in Europe (Prinsen *et al.*, 2011a). These species are generally highly manoeuvrable, with a low wing loading, do not generally fly in large flocks, and have good forward vision. However an investigation of the causes of death of recovered ringed birds in Britain and Ireland (Rose and Baillie, 1992), indicated that raptors are susceptible to collisions with power lines (more information on this study and the raptor species involved is reported in the paragraph below). The authors suggested that this may be due to their spending a large proportion of flying time at potential collision height and employing hunting methods which involve high speed pursuit of prey (Rose and Baillie, 1992). Collision with power lines has also been identified as a significant source of mortality for Bonelli's eagle (*Hieraaetus fasciatus*) and Bearded Vultures (*Gypaetus barbatus*) in France and Spain (Rollan et al., 2010, Margalida *et al.*, 2008). Modelling based on the movements of radio-tracked Bonelli's eagles found that high collision risk was a product of the presence of power lines in areas of eagles' home ranges that were most intensively used and where birds tended to fly at collision height (Rollan *et al.*, 2010). Birds of prey are typically long-lived with low annual productivity (K selected[7]), have fairly small and dispersed populations, and many are at a poor conservation status, thus even low levels of mortality can have a significant impact on populations (APLIC, 1994).

Rose and Baillie (1992) carried out an analysis of the causes of death of ringed birds recovered in the British Isles in relation to power lines. The analysis focused on birds for which the cause of death was recorded under the category 'hit wire', and a 'hit wire' index was calculated for each species to standardise the frequency of recoveries recorded as collisions with wires (and assess the relative vulnerability of each species to collision). Unfortunately, the information associated with ringing recovery did not allow different types of overhead lines (transmission and distribution lines and telephone wires) to be distinguished. Overall there were records of 132 bird species with one or more 'hit wire' recoveries (out of a total of 229 species for which ringing recovery records were held). The total number of ringing recoveries and recoveries in the 'hit wire' category varied between species;

more detailed analysis was possible for species with more data and also more confidence could be placed in the value of ‘hit wire’ indices in terms of implicating collisions with wires as a significant mortality factor. Based on species with over 100 recoveries, the seven with the highest ‘hit wire’ indices (indicating that collisions with overhead wires are likely to be an important mortality factor) were: Mute Swan, Canada Goose, Hen Harrier (*Circus cyaneus*), Merlin (*Falco columbarius*), Peregrine (*Falco peregrinus*), Grey Heron and Common Buzzard (*Buteo buteo*). Five more species with large data sets had ‘hit wire’ indices that also suggested collisions with overhead wires may be a frequent cause of mortality: Lapwing (*Vanellus vanellus*), Tufted Duck (*Aythya fuligula*), Curlew, Sparrowhawk (*Accipiter nisus*) and Common Kestrel (*Falco tinnunculus*). For species with fewer recoveries, Bittern (*Botaurus stellaris*), Bewick’s Swan (*Cygnus columbianus*), Whooper Swan (*Cygnus Cygnus*), Greylag Goose (*Anser anser*), Red Kite (*Milvus milvus*), Marsh Harrier (*Circus aeruginosus*), Montagu’s Harrier (*Circus pygargus*) and Golden Eagle (*Aquila chrysaetos*) had high ‘hit wire’ indices, indicating that collisions with wires may be a risk factor for these species. Considering bird groups (rather than individual species), raptors and waterbirds had the highest ‘hit wire’ indices with shorebirds (waders, gulls and terns) intermediate (Rose and Baillie, 1992). The ‘hit wire’ index was positively correlated with body weight, between and within bird groups.

On the basis of their analysis of ringing recovery data for Britain and Ireland, Rose and Baillie (1992) recommended that, unless there is evidence to the contrary, it should be assumed that all herons, swans, geese and raptor species (including owls) are vulnerable to collisions with overhead wires. A number of other bird species were also identified as potentially vulnerable to power line mortality but with low representation in the ringing recovery data set. These were: gamebirds, waders breeding inland or occurring inland on passage (Dotterel *Charadrius morinellus*, Golden Plover *Pluvialis apricaria*, Woodcock *Scolopax rusticola*, Greenshank *Tringa nebularia* and Ruff *Philomachus pugnax*), Cuckoo (*Cuculus canorus*), and some passerines – in particular those living in open habitats.

Seabirds (other than gulls and terns) generally fly in areas away from power lines and had a low ‘hit wire’ index (Rose & Baillie, 1992). Some seabird collisions (involving Guillemot *Uria aalge*, Cormorant *Phalacrocorax carbo*, and Gannet *Morus bassanus*) were recorded in Central Scotland at a power line crossing the upper Forth estuary, indicative of the use of this area as a flight corridor by coastal and estuarine birds, including seabirds (MBEC, 2005).

2.2.5 Collision Rates and Population-Level Effects

Most of the published studies on power line collisions have focused on short sections (often < 5 km) at areas identified as particular collision hot spots. Estimated collision rates vary from about 0.1 to 489 casualties per km per year (Jenkins *et al.*, 2010; Drewitt and Langston, 2008). Based on studies in the Netherlands, estimates have been produced for different habitats: 113 casualties per km per year in

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[7] Adults place high level of parental investment into producing fewer young.

grassland, 58 per km per year in agricultural land and 489 per km per year near river crossings, (Koops, 1987, cited in Erickson *et al.*, 2005). It is, however, difficult to extrapolate collision risk from one study to other areas or to compare collision rates between studies, because of site-specific conditions and a lack of standard study methods (APLIC, 2012). Thus, the applicability of habitat-specific rates will vary according to geographic variation in the bird assemblage and densities associated with the habitat.

2.2.5.1 Biases in Relation to Estimating Power Line Collision Rates

There are a number of potential causes of bias in relation to collision searches, including the removal of dead birds by scavengers, detectability of carcasses in different habitats and by different observers, and the disappearance of birds which are injured but not immediately killed by collisions. Some studies correct for some or all of these biases, and the application of such correction factors may considerably increase the estimated collision rates. In the absence of corrections for bias, results from studies searching for bird corpses under power lines should be considered as minimum estimates of mortality (Rubolini *et al.*, 2005, Ponce *et al.*, 2010).

Scavenger removal rates are likely to vary with the size of bird and to be highest for the smallest bird species which could potentially be carried off by many scavenging animals. Larger birds are more difficult for smaller predators to remove and are more likely to be scavenged in situ. Carcass removal experiments carried out in conjunction with searches for transmission line collision victims at Dungeness, southern England, used House Sparrows (*Passer domesticus*). A high rate of removal was found, indicating that only 15 % of the bodies of small passerines killed at power lines in a week would be found during searches. On the basis of these experiments it was suggested that adjusting for scavenger removal would increase the total number of collision deaths during the study period from 1,285 (which included 872 passerines) to over 6,000 (Scott *et al.*, 1972).

Scavenger removal experiments carried out in relation to transmission line studies in Central Scotland used carcasses of Pink-footed Geese (*Anser brachyrhynchus*) and Red-legged Partridge (*Alectoris rufa*) to investigate removal rates of 'large' and 'medium' size birds (MBEC, 2005). At two scavenger study plots, the percentage of goose carcasses visible for 14 days after laying-out was 90 % and 77 %; for partridge the equivalent values were 54% and 20%. For studies of birds and transmission lines at a coastal site in North Wales, scavenger removal experiments were carried out with corpses of road-killed birds: Magpies (*Pica pica*), Blackbirds (*Turdus merula*), Wood Pigeons (*Columba palumbus*) and Pheasants (*Phasianus colchicus*) (Henderson et al., 1996). Estimated removal rates were 2 % over 5 days and 6.7 % over 14 days, indicating that respectively 98 % and 93.3 % of carcasses persisted for 5 and 14 days. Carcass removal trials at an upland wind farm in Central Scotland (in relation to studies of wind-farm collisions) indicated that carcasses of female Pheasants were partly or completely scavenged within 5 days after laying out (in the absence of snow cover) but that feathers from eight of nine carcasses were still visible after 90 days (Duffy and Steward, 2008). These examples, and other studies (e.g. Ponce *et al.*, 2010), indicate that scavenger removal rates, and the period of time over which traces of carcases are potentially detectable, vary between locations.

In addition to carcass size, carcass removal rates have been found to be affected by carcass density, scavenger abundance and activity (which may vary seasonally), vegetation type and weather conditions (Schutgens *et al.*, 2014 and references therein). At Dungeness, House Sparrow corpses were removed at a higher rate from beneath power lines compared with a control area in similar habitat away from the lines, indicating that scavengers may have been concentrating their efforts on power line areas where collisions were frequent (Scott *et al.*, 1972). Excluding small birds, Rioux *et al.* (2013) found that removal rates of medium-sized to large birds by scavengers were highly variable and averaged 39% (n=37, 95% confidence intervals ±11%, coefficient of variation 84%) after seven days (corresponding to the most frequent sampling interval in the literature) across 16 studies reviewed. Scavenger removal of carcasses tends to occur shortly after death (Smallwood, 2007); for example, Ponce *et al.* (2010) reported that the number carcasses removed in a trial in Spain increased logarithmically, with 32% gone 2 days after placement and thereafter only 1.5% removed on a daily basis by day 28. In South Africa, Schutgens *et al.* (2014) found that 16% of carcasses laid out were removed during a 90-day trial period, all within the first three weeks.

Observer search efficiency trials, carried out for transmission line studies in Central Scotland, found that two observers showed a mean search efficiency of 95 % for goose carcases at each of two sites, whereas mean search efficiency for partridges was 40 % at one site and 60% at the other (MBEC, 2005). Similar trials in upland areas of Central Scotland, carried out for a wind farm mortality study, found that an observer located 89% of the carcasses of female Pheasants in the absence of snow, and 74% in a trial where snow fell (Duffy and Steward, 2008). Based on a review of 12 studies, Rioux et al. (2013) found that observer efficiency averaged 80% for medium sized to large birds and that there was a high degree of consistency between studies (95% confidence intervals ± 5%, coefficient of variation 18%). In Spain, Ponce *et al.*, 2010 found that detection rates increased with the observer's previous experience and recommended that all personnel participating in carcass searches should be trained; a South African study, however, observer experience did not significantly affect detection rate (Schutgen *et al.*, 2014).

Few estimates of crippling bias have been found. This could reduce mortality estimates from corpse search studies if some birds collide with wires but are able to continue flying or walk away from the study area before succumbing to injuries. Crippling rates are particularly difficult to estimate because they require observations of birds hitting a power line, continuing their movement beyond the power line, and, strictly speaking, knowledge of whether the bird succumbs to collision injuries, although a worst case scenario would be to assume that all birds which strike power lines eventually die from injuries.

Collisions with power lines are relatively rare events and considerable time and effort is required to observe them. A study of birds flying across power lines in South Carolina between 1991 and 1994 (Savareno et al., 1996), clocked up 4750 observer hours at two study sites, during which time 34 bird collisions with power lines were observed (and one bird collision with a guy wire for a power line). Overall, 25 birds of the 34 which collided with the power lines flew out of the search corridor, as did the bird that collided with the guy wire, yielding a crippling bias of 74 %. Similar estimates of crippling bias were recorded by Meyer (1978): 75%; and James and Haak (1978): 73 % (cited from APPLIC, 2012). Faanes (1987) recorded 109 birds colliding with power lines during flight observations at seven study sites in North Dakota (no details of observer effort are provided) but did not provide any information on the fate of birds after collision or any estimate of crippling bias. Crowder (2000) observed 11 birds colliding with power lines during more than 700 hours of power line observations in Indiana, and of these only two fell within the search zone, giving an 82% crippling bias. Observations of flight activity over 643 hours at three power line sites in New Mexico recorded two fatal collisions and three apparently non-fatal collisions where birds continued flying until they were out of sight of observers (EPG 2011), suggesting a crippling bias of 60%.

Mute swan carcasses from collisions with transmission lines close to Abberton Reservoir, England, were found at distances of 10-351 m from power lines (Frost, 2008). It is noted that some birds were clearly injured (rather than being killed outright) and able to crawl away from the collision point before death, but no indication of the number of birds involved is provided. A Dutch study reported that wounded, radio-tagged birds were traced as far as 2 km from the point of collision (Heijnis, 1980 cited in Bevanger, 1999). MBEC (2005) reported that up to 75 % of waterfowl may initially survive collisions with power lines (citing Savereno *et al.*, 1996 and Anderson, 1978) although in their study of birds and power lines in Central Scotland they assumed that all non-glancing collisions of large birds such as geese with transmission lines would result in instant death or incapacity and did not include a correction for crippling in the reporting of collision mortality results. Bevanger (1999) cites three studies which estimate crippling rates of 22 % (Hiltunen, 1953), 50 % (Renssen *et al.*, 1975) and 74% (Beaulaurier, 1981), to illustrate the possible variation in this factor. Rioux *et al.* (2013) reviewed studies of power lines and bird mortality and found only four studies that measured crippling rates appropriately (this includes studies by Crowder, 2000 and Savereno *et al.*, 1996, summarised above, with the results from the two study sites considered in the latter study presented separately), with an average of 80% and low variability (95% confidence intervals ±4%, coefficient of variation 17%). If 80% of birds striking power lines are crippled rather than killed outright, and move out of the study area where corpse searches are carried out, then crippling rates could have a major effect in terms of increasing power line mortality rates.

Few details are available in the studies cited above of the species involved in records of birds which collide with power lines but continue flying. The size of a bird may be a factor due to flight dynamics, a large bird such as a swan which tips a wire is more likely to fall to the ground and sustain fatal injuries than a smaller, lighter bird that may be able to recover its flight mid-air and die later at some distance away. Thus smaller birds might have a higher crippling bias than larger birds (W. Brown, pers. comm., cited in APLIC, 2012).

In addition to the factors discussed above, the habitat beneath a power line can also affect the number of bird corpses which may be found and hence the estimated collision mortality (Crowder, 2000). Birds which strike power lines crossing or close to water may fall into water and be washed away, and terrestrial habitats with taller vegetation are more difficult to search. No studies have been found which attempt to provide estimates of bias for different habitat types. In their guidelines for experiments to test the efficiency of wire marking devices in reducing bird collisions, Barrientos *et al.* (2011) suggest studying marked and unmarked lines in areas of similar vegetation and topography, presumably to minimise any bias associated with habitat differences.

2.2.5.2 Comparison of collision rates and flight activity

Some studies – largely those that have investigated the impacts of wire markers to reduce bird collisions - have recorded flight behaviour in the vicinity of power lines in conjunction with searches for bird remains, so that collision rates could be compared with flight activity. Barrientos *et al.* (2011) carried out a meta-analysis of studies with flight frequency data which involved comparisons on marked and unmarked power lines. They searched scientific databases and the internet and also contacted authors and organisations (government and non-government) who have worked on birds and power lines. They found 11 studies from Spain, Germany, USA and Colombia, including 15 separate wire-marking experiments, 7 published in scientific journals and 8 in unpublished reports. Overall the studies found collision rates of 0.21/1000 bird's crossing at unmarked lines (with no devices to deter birds from colliding with wires) (Barrientos *et al.*, 2011). This indicates that, overall, 99.979% of birds avoided collision.

In theory a study could compare collision rates estimated from observations of birds crossing power lines with those estimated from searches beneath power lines for a given area. Such a study would be resource intensive, however. Many hundreds of hours of field observation of flight activity would be required, as collisions are rare events, including observations during darkness. As well as collision rates, it should be possible to estimate crippling bias from flight activity records. Searches for bird remains beneath power lines would require accompanying investigations of site-specific scavenger removal rates and observer search efficiency.

2.2.5.3 Estimates of Power Line Mortality at National and Worldwide Scales

A few studies have estimated avian power line mortality at a national scale based on available estimates of collision victims per km of transmission line and the extent of transmission lines. Respective totals of 750,000 – 1 million, 30 million and 130 million bird deaths per year have been estimated for the Netherlands, Germany and the United States (Koops, 1987, Hoerschelmann *et al.*, 1988 and Erickson *et al.*, 2005, cited in Prinsen *et al.*, 2011a). The estimate for the United States was actually based on that for the Netherlands: a mean estimate (adjusted for scavenging and searcher efficiency bias) of 261 deaths per mile per year (163 per km per year) was derived from an estimated 750,000 deaths per year for 2875 miles (4,600 km) of power line in the Netherlands; this was extrapolated to 500,000 miles of bulk transmission lines in the US (Erickson et al., 2005) to produce an estimate of 130 million bird deaths per year. Rioux *et al.* (2013) used three methods to calculate national estimates of bird collision mortality at transmission lines in Canada, based on: available published studies that met certain criteria; studies from areas close to/geographically similar to Canada; and estimates stratified by location and habitat (thus no specific field studies were carried out in Canada to derive these estimates). Depending on the bias corrections applied, estimates ranged from 1 million to 229.5 million birds per year; the most realistic estimate was considered to be between 2.5 and 25.6 million birds per year. Worldwide, it has been estimated that bird deaths due to collisions with power structures, including transmission and distribution lines, could approach 1 billion per year (Hunting, 2002, cited in Barrientos *et al.*, 2011).

Given the high variation in mortality rates reported from different studies, such estimates must be considered as crude at best, and (not surprisingly) no attempt has been made to provide any breakdown of the estimated mortality by bird species. Production of reliable estimates of power line mortality at national scales would require a dedicated study involving fieldwork conducted over several years, with considerable spatial coverage and high sampling intensity, and adequate attention to the various biases outlined above.

2.2.5.4 Population effects of Power Line Mortality

Most studies conclude that power line casualties are not likely to adversely affect bird populations, usually on the basis that the mortality is highly localised and that it is often the more common and widespread species that are most affected (Jenkins *et al.*, 2010). However, in combination with other anthropogenic mortality factors it may become a factor of concern (Prinsen *et al.*, 2011a). Erikson et al. (2005) estimated that, after collisions with buildings/windows, collisions with power lines were the second most important human-related cause of death for birds in the USA. Overall population impacts of power line collisions will depend on whether mortality is additional to natural mortality (it could be compensatory if individuals colliding with power lines were those most susceptible to death from natural causes (e.g. because they were weakened or diseased). Collision mortality has been implicated as a significant factor in the decline of some endangered birds, particularly larger species with small populations, including raptors, cranes, bustards and pelicans (Prinsen *et al.*, 2011a, Jenkins *et al.*, 2010).

2.2.6 Mitigation to reduce the risk of bird collisions with power lines

Mitigation measures can be employed to reduce the risk of bird collisions with power lines. These include sensitive route planning, modification of transmission lines and habitat management (APLIC, 2012: Prinsen *et al.*, 2011a, b), all of which are discussed below.

2.2.6.1 Route Planning

Route planning is a key factor at the planning stage for new power lines. All new transmission lines should be subject to an environmental assessment. For birds this should consider the bird species likely to be impacted and the areas likely to be at highest risk in terms of collision mortality (e.g. high densities of birds and/or concentrations or important populations of species at risk of collision). Where lines may pass close to areas with areas identified as high risk for birds, these areas could be avoided if possible. Lines can be positioned in relation to landscape features or bird flight paths to minimise collision risk, or modification of power lines to reduce collision risk can be employed.

Landscape features such as valleys, rivers or shorelines may concentrate birds into relatively narrow flight paths, and preferably new power lines should be routed parallel rather than perpendicular to such features (APLIC, 2012; Prinsen *et al.*, 2011a, b). As an example, the shingle headland at Dungeness, on the southeast coast of England, is a focal point for bird migration. A study undertaken between 1964 and 1970 found 1,285 bird casualties under a stretch of 2.16 km of 400 kV transmission line running in a westerly direction from the nuclear power station, roughly parallel to the shoreline and across the regular flight path of migratory birds (Scott *et al.*, 1972). It was suggested that the number of collisions would have been fewer if the power lines ran north rather than west from the power station, so that the lines ran parallel to, rather than across, the main flight route of migratory birds in this area.

2.2.6.2 Modification of Power Lines

Modification of power lines can include measures to make lines more visible and removal of earth/ground wires.

Fitting power lines with devices to make them more visible to flying birds is widely used to mitigate bird collisions. A wide range of wire marking devices has been used, generally falling into three basic designs: spiral devices which wrap around the wire (and may act to reduce line vibration as well as making power lines more visible to birds), hanging devices which are suspended from the wire with fixed or swinging plates or flappers; and spheres (also known as aviation balls). Examples of line markers of these three design types are shown in Figure 1. APLIC (2012) includes detailed information on a range of devices as well as considerations for use in different circumstances. Some devices are luminescent, intended to be visible to bird species flying at night. Photographs of a range of devices are included in Prinsen *et al.* (2011a and b).

The available evidence suggests generally positive results. APLIC (2012), Prinsen *et al.* (2011a) and Jenkins *et al.* (2010) provide a number of examples of quantitative studies which illustrate the effectiveness of various devices in reducing avian collision mortality. Many studies report reductions in collision rates of 50% or more, although the effectiveness of marker devices varies between studies and species. For example, fitting spiral flight diverters to an area of power line close to Abberton Reservoir in England resulted in a 95% reduction in the mortality of Mute Swans (Frost, 2008). An early study found no evidence that either bands of luminous orange tape wrapped around earth wires, or trailing bands of tape with 5 cm tails, reduced collision mortality at Dungeness, England (Scott et al., 1972); although it was reported that fitting of 15 cm black tapes to earth wires in the Teesmouth area of England in 1964 and 1966 reduced bird casualties (Angela Cooper in litt cited in Scott *et al.*, 1972).

Studies reporting positive results may be more likely to be published, although a meta-analysis of 7 published and 8 unpublished experimental studies (Barrientos *et al.*, 2011, see also 2.1.3.2 above) found an overall mortality reduction of 78% at marked wires (collision rates of 0.21/1000 bird crossings at unmarked lines and 0.05/1000 crossings at marked lines).

Robust comparative evidence on the effectiveness of different types of flight diverters is generally lacking (e.g. due to differences in study designs and site-specific conditions, APLIC 2012), but important factors appear to be size and spacing. A recent large-scale trial in central Spain found a small (9.6 %) but statistically significant decrease in bird casualties during corpse searches at power lines after line marking with spirals (Barrientos *et al.*, 2012); there was no influence of marker size (small versus large spirals) when all bird species were considered together but for one species - Great Bustard - mortality was slightly lower when lines were marked with large spirals. A study in the north of England, beginning in August 2013, aims to investigate the efficacy of different types of bird diverters on power lines, with a focus on geese and swans (WWT, 2013).

Jenkins *et al.* (2010) state that in general, any sufficiently large marker (which thickens the appearance of the line at that point by at least 20 cm, over a length of at least 10-20 cm), placed at regular intervals (every 5-10 m) on the earth wires (preferably) or the conductors, is likely to reduce collision rates by 50-80%. In addition, line markers should incorporate as much contrast with relevant backgrounds as possible (colour is probably less important than contrast) (Prinsen *et al.*, 2011b). There is evidence that bird collisions tend to occur towards the centre of the span of wires rather than close to the pylons or poles, such that bird flight diverters could be effective if installed only on the central 60% of a span (APLIC 2012). However this is recommended only for lines of 132 kV and above (Prinsen *et al.*, 2011b).

Notably, little progress appears to have been made in developing or assessing the effectiveness of markers for preventing nocturnal collisions, although these may make an important contribution to the total numbers of casualties (Jenkins *et al.*, 2010). Prinsen *et al.* (2011a) cite a Dutch study which found an 80% reduction in nocturnal collisions of ducks when power lines were fitted with bird flappers, but a negligible reduction in collision mortality of Coots (Fulica atra) for which nocturnal collisions were also thought to be important. Devices that are visible at night (e.g. through luminescence) have been developed and may be advantageous, but their effectiveness is not proven and there is the possibility that birds might be attracted to illuminated objects in darkness (Prinsen *et al.*, 2011b).

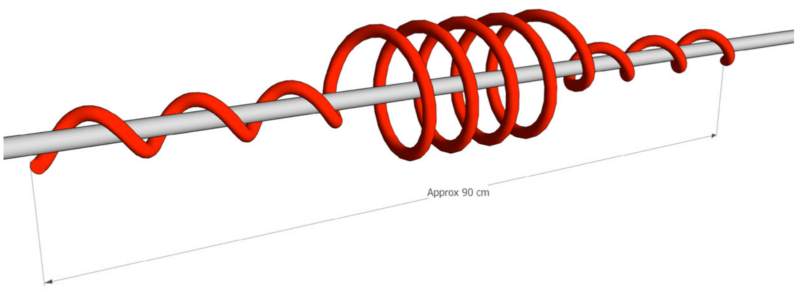
Experience with the use of different types of wire markers indicates that there are design and other constraints in some situations. Addition of devices to a power line adds to the wind and ice loading (APLIC, 2012). At Dungeness, the wind resistance of power cables in an exposed area prevented the use of corks or ball markers (Scott *et al.*, 1972). Spiral Vibration Dampers used in San Luis Valley, Colorado, were found to be effective in reducing the mortality of waterfowl but to cause line wear (Brown and Drewien, 1995). New generations of devices have reduced this issue while retaining effectiveness in relation to reducing bird collisions (APLIC, 2012).

It is recommended that the choice of marking device is based on consideration of a number of issues, including product effectiveness, availability and durability, cost, ease of installation, and structural constraints such as wind and ice loading (APLIC, 2012; Prinsen *et al*., 2011b). Ideally a wire-marking device should last as long as the wire itself. This may not be achievable in practice but to ensure maximum durability, all steel components of devices should be made of stainless steel and plastic components should be UV stable high impacted PVC (Prinsen *et al.*, 2011b, who also provide further detailed suggestions on ensuring durability).

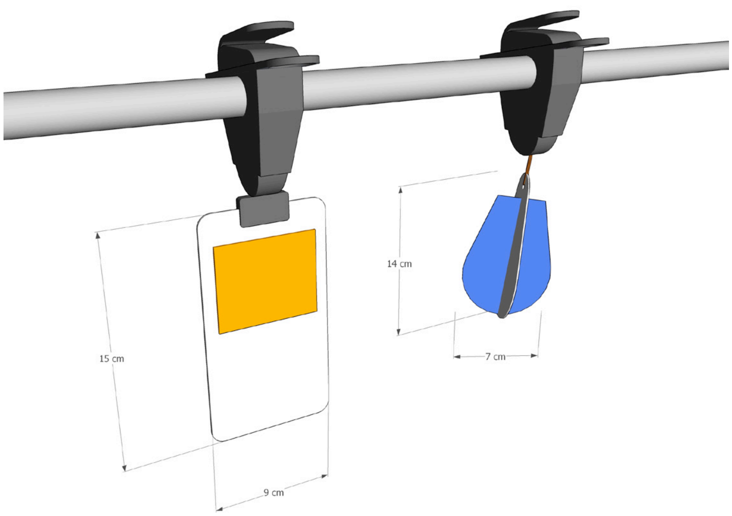
An experimental study in Norway found that removal of the earth wire from a section of power line in Norway reduced the number of grouse collisions by half (Bevanger and Brøseth, 2001). It is recognised that there are safety issues related to the removal of earth wires, but this could be considered as mitigation for power line mortality in areas where lightning is not an issue, or where lightning arresters can be used (APLIC, 2012).

Figure 1: Examples of marking devices to make wires more visible to birds

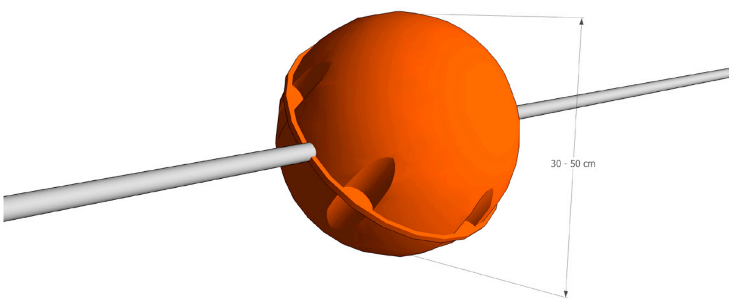
(a) Swan flight diverter (spiral)



(b) Hanging tags



(c) Marker spheres



2.2.6.3 Habitat Modification

Modification of habitat in areas close to power lines can reduce collision risk. For example, planting trees which will grow above the height of power lines may force birds to gain sufficient altitude to clear the trees and the power line; although this is obviously a long-term strategy which may require alternative mitigation before trees mature (APLIC, 2012). Alternatively the potential for existing areas of woodland to reduce collision risk might be taken into account when planning power line routes. In Portugal, off-site mitigation has been carried out to compensate for the impacts generated by a Power Line on Golden and Bonelli's Eagles. This involved habitat management to promote prey populations within raptor territories but away from the power line infrastructure to reduce the potential for interactions between eagles and power lines (Paula *et al.*, 2011).

2.2.6.4 Underground Cabling

Underground cabling of transmission circuits obviously offers the best solution against bird collisions (and electrocution), although it is recognised that this is not always feasible from an energy security perspective. It is also considerably more expensive than overhead power lines and may result in increased impacts on other environmental receptors (Prinsen *et al.*, 2011b). However, underground cabling of transmission lines in areas of particularly high risk for avian collision could be considered (APLIC, 2012).

2.3 ELECTROCUTION

Electrocution of birds occurs when they make simultaneous contact with the energised and grounded sections of a power line, or between two phase conductors. This may occur when a bird is landing or taking off and the wings bridge the gap between wires, when a bird, nesting material or prey bridges the gap between the wires and a grounded power pole or pylon, or (rarely) when a bird touches only one conductor (Prinsen *et al.*, 2011a). Electrocution normally results in the death of the bird and can cause power cuts. It occurs mainly on smaller, lower voltage distribution lines and affects mainly large birds such as raptors and storks, species with wingspans which are sufficiently large to bridge the gap between wires (Lehman *et al.*, 2007). Often this involves species such as eagles and vultures using pylons as hunting perches in habitats lacking natural perches (Lehman *et al.,* 2007). In Ireland, there are no bird species with wing spans large enough to bridge the gap between conducting wires of transmission lines, so the risk of electrocution on the high voltage transmission lines of the national grid is very limited, as discussed below.

As is the case with collisions, there are a large number of studies which document the electrocution of birds on power lines, including studies based on corpse searches. It is possible to distinguish between birds which have been electrocuted and those that have collided with wires, but this depends on factors such as the time after death, the completeness of remains and degree of decay, and studies vary in the amount of detail provided on how mortality was assigned. Only a few studies report electrocution mortality as a rate (variously deaths per pole, per km, per month or year). For example

Rubolini *et al.* (2005) present electrocution results from bird corpse searches at power line sites in Italy and quote minimum mortality indices (uncorrected for any bias) of 2.1 to 20.5 birds per km of power line per year, at six medium voltage lines; it is noted that censused sections of power lines were not distributed at random but represent 'worst case' scenarios, presumably because they were focused on areas of power lines where bird mortality had been identified as an issue. Comparing quantitative estimates of casualties for electrocution is even more difficult than for collisions because of the indications that electrocution risk may be highly site specific – associated for example with a particular combination of power line and environmental characteristics. Estimates of mortality at large scales requires a representative sample of sites, repeated corpse searches for a specified time, and adjustment for biases such as scavenger effort (Lehman *et al.*, 2007).

2.3.1 Factors Influencing Electrocution

2.3.1.1 Characteristics of Birds

Electrocution with power lines mainly affects larger bird species such as birds of prey and storks, of sufficient size to bridge the gap between wires (Janss, 2000; Bevanger, 1998).

Mortality from electrocution with power lines was identified as a conservation problem for birds of prey in North America in the early 1970s. Large birds of prey, particularly Golden Eagles, were reported as being especially vulnerable (Watson, 2010: Lehman *et al.*, 2007; Kochert and Olendorff, 1999; APLIC, 1996; Olendorff *et al*., 1981). Around this time, it was estimated that 300-2,000 Golden Eagles were killed annually on power lines in the USA (Watson, 2010). Deaths occurred largely on low voltage distribution lines (12-24 kV) with wooden poles about 8-10m high and wires spaced less than 1m apart. High voltage transmission lines (69 kV) were not a problem because the conducting wires were 3m or more apart (Watson, 2010; Lehman *et al.*, 2007).

In Europe a wide variety of raptors, storks, owls, corvids and other passerines of all sizes are reported to suffer electrocution on power lines (Prinsen *et al.*, 2011a). White Storks (*Ciconia ciconia*) and Eagle Owls (*Bubo bubo*) are commonly reported as victims. Electrocution has been identified as a serious threat to a number of large eagle species, including the endangered Spanish Imperial Eagle (*Aquila adalberti*) (Sanchez *et al.,* 2008), the Eastern Imperial Eagle (*Aquila heliaca*) in Hungary (Horváth *et al.*, 2011) and Bonelli's Eagle in Spain (Real *et al.*, 2001). Electrocution accounted for 14 of 266 (5 %) deaths of Golden Eagles reported in a Spanish study (Arroyo *et al.,* 1990, cited in Watson, *et al.*, 2010) and the species has been identified as at risk of electrocution in Sweden and Hungary. There appear to be few reports of White-tailed eagle (*Haliaeetus albicilla*) casualties, although the species is identified as at risk of electrocution in Sweden (Prinsen *et al.*, 2011a). Lehman *et al.* (2007) report that the raptor species most often found beneath power poles in Europe include Common Buzzard, Red Kite and Common Kestrel, and Bayle (1999) reports that 30 of 37 species of raptors breeding or wintering in Western Europe have been killed on power lines through electrocutions or, to a lesser extent, collisions with wires, with medium voltage powerline (1-60 kV) responsible for most raptor deaths.

Age and behaviour may affect the probability of electrocution. Young Golden Eagles are less adept at flight and more susceptible to electrocution (Watson, 2010; Olendorff *et al.*, 1981). Eagles and vultures often use pylons or poles as perch sites for hunting, and a few species such as Osprey and White Stork, may nest on pylons (Lehman *et al.,* 2007; Meyberg *et al*., 1996). Female Spanish Imperial Eagles are at greater risk of electrocution because of their larger size (Ferrer & Hiraldo, 1992) and the same may be true for other large raptor species with reverse sexual dimorphism (where females are larger than males).

2.3.1.2 Environmental Factors

High mortality of large birds of prey due to electrocution is associated with the use of power lines as perches where they pass through flat landscapes with few alternative perches (Watson, 2010; Lehman *et al.*, 2007; Real *et al.,* 2001). As reported above, mortality is largely associated with lower voltage distribution lines, rather than high voltage transmission lines, because of the spacing of the conducting components. For distribution lines, mortality tends to be most prevalent at particular poles, for example located on small hills or ridges with good views and updraughts (Prinsen *et al.*, 2011a; Watson, 2010).

Weather conditions can affect electrocution risks due to reduced flight manoeuvrability in high winds and increased conductivity of wet feathers (Lehman *et al.*, 2007; Olendorff *et al.*, 1981).

2.3.1.3 Power Line Design Characteristics

Power line type and configuration influences electrocution risk (Kochert and Olendorff, 1999). The spacing between energised wires and earth wires, or energised wires and other conducting structures is a key factor. Nearly all electrocutions that occur in the U.S. are on low-voltage power lines (<69kV) where the spacing of the wires is close enough to be bridged by larger birds; whereas the conducting wires of the high voltage transmission lines are spaced more widely apart (Watson, 2010; APLIC, 1996; Olendorf *et al.*, 1981). Most raptor electrocutions in South Africa also occur on low to medium voltage structures (22–88 kV) (Lehman *et al*., 2007). Poles with additional hardware can result in higher bird mortality rates if this increases the number of energised components and reduces their separation (Harness and Wilson 2001; Olendorff, 1981; APLIC, 1996).

In Europe most utility structures and crossarms are constructed of steel or steel-reinforced concrete and are conductive and grounded by design (Janss, 2000; Bayle, 1999). A bird perched on a crossarm may be electrocuted by making contact with just one conductor (Bayle, 1999 and Janss and Ferrer, 1999). This may be why more, smaller birds are affected by electrocution in Europe compared with other areas of the world (Bayle, 1999; Janss, 2000), although based on published studies the risk appears to be related to distribution rather than transmission lines.

2.3.1.4 Electrocution Rates and Population Effects

In most countries the overall scale of electrocution is unknown. It has been identified as a major problem in the Slovak Republic where Adamec (2004) reported annual mortality levels exceeding 10,000 birds in relation to 22 kV power lines.

Electrocution has been identified as a key cause of decline for a number of endangered species in Europe, including the Spanish Imperial Eagle (*Aquila adalberti*, López-López *et al.*, 2011; Sanchez *et al.* 2008) and Bonelli's Eagle (Real *et al.*, 2001), and addressing this issue is a key action for the conservation of these species.

2.3.2 Mitigation

As for collision risk, route planning for new transmission lines can be assessed to minimise the likely electrocution risk, and underground cabling is the best solution to eliminate risk.

Specific mitigation measures for the prevention of electrocution involve the design or modification of power lines to adjust the spacing of energised wires, or wires and conducting structures, to minimise the chance of birds bridging the gap; or insulating live components to prevent electrocution of birds which may alight on them or brush against them. In general, these risks are low on high voltage transmission lines due to the larger spacing of conductors and the arrangement of insulating components on support structures (with wooden poles for 110kV and steel lattice towers for higher voltages being used in Ireland, EirGrid, 2012). Thus the mitigation measures referred to below apply mainly to distribution lines.

In a number of countries in Europe, namely the Netherlands Belgium, the UK, Norway, Denmark and Germany, low and medium voltage distribution lines have been, or are in the process of being, cabled underground. High voltage transmission lines, however, are still being built overground. Electrocution of birds is absent or has been markedly reduced in these countries (Prinsen *et al.*, 2011a).

Because electrocution risk to birds tends to be focused at a few poles or pylons which account for most deaths and these structures are usually associated with distribution rather than transmission lines, mitigation may be selectively applied to higher risk structures. This can be carried out pro-actively for new power lines – by using predictive analyses to identify high risk poles (Lehman *et al.,* 2007*;* Maňosa, 2001), or reactively for existing power lines where electrocution of birds has been identified as a problem. Dwyer *et al.* (2014) analysed data from southern California to identify patterns of avian electrocution and developed a predictive model for the electrocution risk associated with poles carrying power lines. Tests of the model indicated that it could be used to identify higher risk poles for retro-fitting of measures to prevent electrocution of birds. Provision of alternative (and more attractive to birds) perches or nest sites close to electricity support structures may also be used to attract birds away from pylons and poles. All these measures apply mainly to lower voltage distribution lines rather than transmission lines.

Some examples of specific modifications of power lines to mitigate against electrocution are included in Prinsen *et al.* (2011a). Specific studies and electrocution mitigation measures have been carried out for some species and resolving electrocution issues has been critical to the survival of the Spanish Imperial Eagle (López-López *et al.*, 2011).

2.4 CONCLUSIONS: POWER LINE MORTALITY RISK FOR BIRDS IN IRELAND

The risk of electrocution of birds is considered to be low on electricity transmission structures in Ireland because of the design of poles and pylons and the wide spacing and arrangement of conductors. New transmission lines to be constructed in the future will be at 110 kV, 220 kV and 400kV (EirGrid, 2008). Conductor spacing for 110 kV lines is 4.5m, which is almost double the wing span of the largest Irish bird species such as Mute Swan and White-tailed Eagle. In addition, the design of structures is such that contact between conducting wires and grounded components is not possible (EirGrid, 2012). Examples of typical pylon and pole structures used in Ireland are shown in Figure 2. Studies worldwide indicate that it is only on lower voltage distribution lines that conducting wires and/or earthed components are placed sufficiently closely for even larger birds to touch two wires simultaneously, and larger bird species are most at risk of electrocution because they are most likely to bridge the gap between conducting wires.

Based on the characteristics of birds known to be vulnerable to electrocution elsewhere, if there were any risk of electrocution to birds on transmission lines in Ireland, the species involved could include the larger species of raptor: Golden Eagle, White-tailed Eagle, Red Kite, and Common Buzzard. The first three are of particular conservation concern as all have been recently re-introduced to Ireland. In Britain, mortality of Golden Eagles due to electrocution appears to be rare, probably because there are few power lines over most of the species' range in upland Scotland, and where lines do occur there are plenty of alternative perches. Nevertheless, 5 of 146 (3%) golden eagle corpses found in Scotland and submitted to the Institute for Terrestrial Ecology and the Scottish Agricultural Science Agency for analysis between 1963 and 2009 died of electrocution, and Watson (2010) indicates that further research would be merited. Compared with golden eagles, electrocution risks might be expected to be higher for some of the other larger raptors (e.g. red kites) in Britain (and potentially also Ireland) because these species are less restricted to upland areas with few power lines.

Collision with wires is the main potential threat of transmission lines to birds in Ireland. In relation to morphology and behaviour, studies indicate that risk factors for collision include poor flight manoeuvrability, blind spots in the visual field or poor acuity, flying at night or in low light levels, flocking behaviour, and the amount of time spent flying at collision risk height with power lines. A review of the causes of death of ringed birds recovered in Britain and Ireland (Rose and Baillie, 1992) suggested that all herons, swans, geese and raptor species (including owls) are vulnerable to collision with overhead wires, and that gamebirds, waders breeding inland or occurring inland on passage, cuckoos and some passerines were potentially vulnerable (the latter species groups had lower sample sizes in the data set). Most of these species, with the exception of smaller raptors, have also been identified in other studies reviewing the susceptibility of birds to collision with power lines at in Western Europe, other regional scales or worldwide (Prinsen *et al.,* 2011a; Jenkins *et al.,* 2010, Bevanger, 1998). These reviews also highlighted a number of other species groups as vulnerable to collision, of which rails and crakes occur in Ireland.

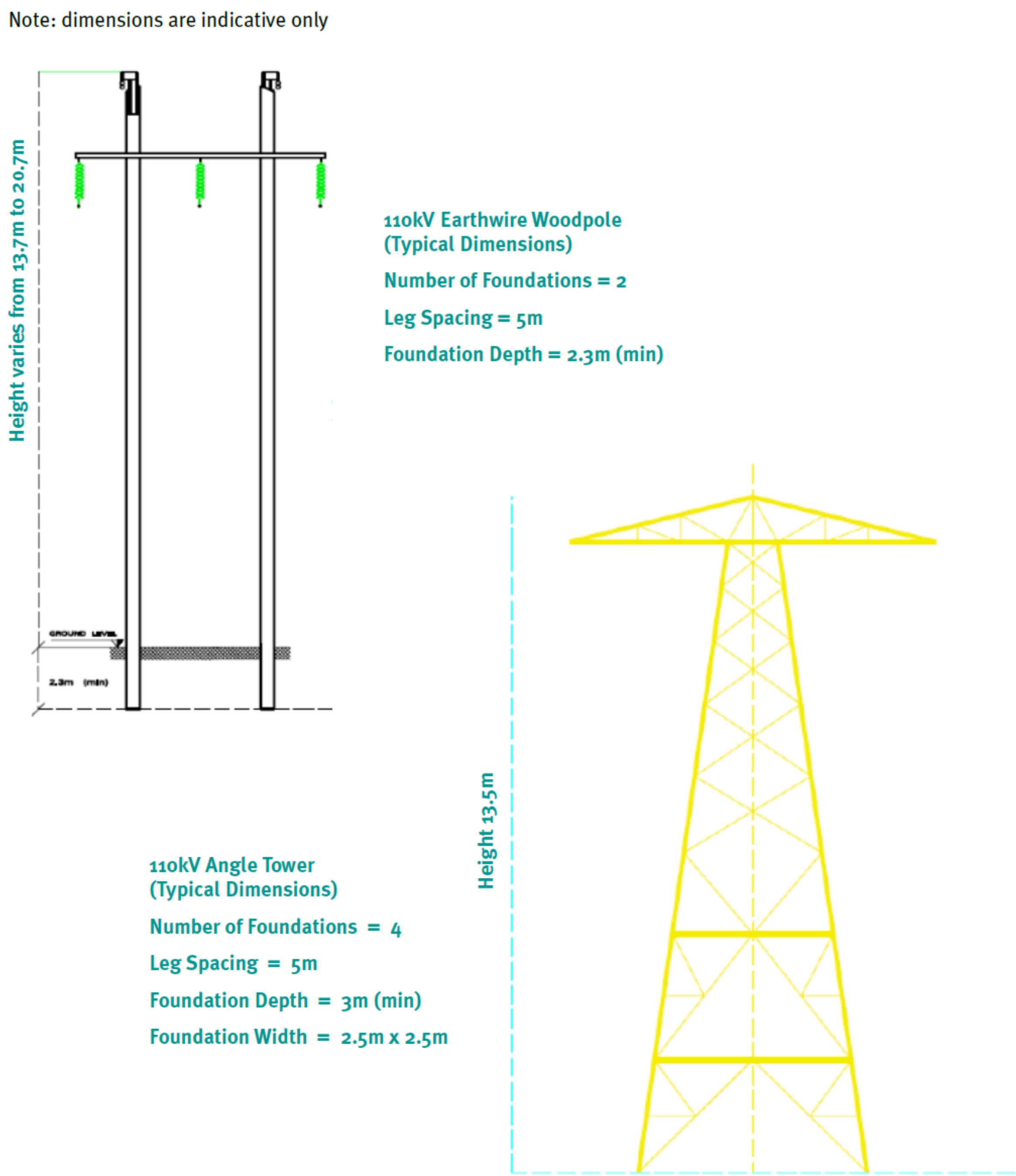
EirGrid Ecology Guidelines for Electricity Transmission Projects (EirGrid, 2012) features a proposed matrix for assessing the vulnerability of bird species in Ireland to collision with transmission lines. The findings of the current review suggest some amendments to this to recognise the greater susceptibility of some species – notably raptor species and grey heron. Mitigation measures have been developed for both collision and electrocution of birds.

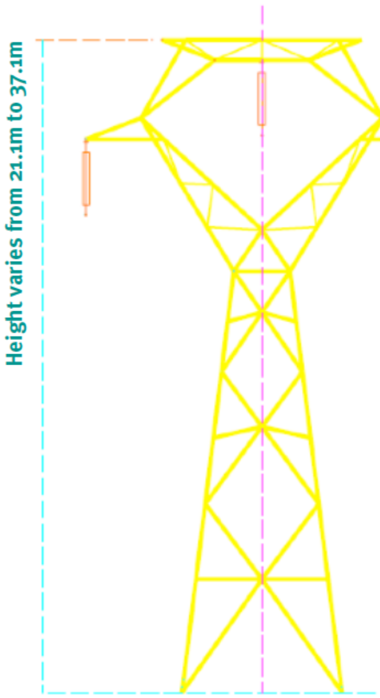
Avoidance of important bird areas is a primary factor in the early planning stages for all new transmission lines, in particular areas which support concentrations of species such as waterfowl which are vulnerable to collisions. In Ireland, all new transmission lines are subject to environmental assessment which includes consideration of potential impacts on birds. An Environmental Impact Statement (EIS) is required by law for developments involving transmission of 200 kV or more by overhead cables and a length of more than 15 km. Developments involving overhead cables of less than 200 kV, or 200 kV cables less than 15 km in length may require an EIS if there are likely to be significant impacts on the environment. Transmission projects which do not require an EIS will still require an Environmental Report which considers ecological risks (EirGrid, 2012). There is a very detailed corridor selection process for transmission line routes. High risk areas – including those for birds - are identified early in the planning phase and routes are designed to avoid these wherever possible.

Fitting transmission lines with devices to make them more visible to flying birds is widely used to mitigate bird collisions at high risk sites. A meta-analysis of experimental studies (confined to studies with flight frequency data as well as corpse searches) found an overall mortality reduction of 78% at marked compared with unmarked wires (Barrientos *et al.*, 2011). Jenkins *et al.* (2010) concluded that, in general, any sufficiently large marker (which thickens the appearance of the line at that point by at least 20 cm, over a length of at least 10-20 cm), placed at regular intervals (every 5-10 m) on the earth wires (preferably) or the conductors, is likely to lower collision rates by 50-80%. The effectiveness of markers for preventing nocturnal collisions, which may make an important contribution to the total numbers of casualties, is not proven, although luminescent devices are available which are intended to be visible to birds flying at night.

Published studies indicate that preventative and mitigation measures have proven to be effective in reducing the level of bird mortality from both electrocution and collisions. However, it is generally not feasible to mitigate impacts on birds along the full extent of a national transmission network. Therefore, a strategic approach is most appropriate, prioritising potentially problematic sections of transmission lines based on environmental factors associated with high risk areas and the distribution of species of conservation concern. In order to assess the effectiveness of this approach, standardised protocols for research and monitoring should be established to generate estimates of bird mortality, address bias factors and enhance the accuracy of prediction for future power line developments (Prinsen *et al.*, 2011a; Lehman *et al.*, 2007).

Figure 2: Typical Electricity Structures used in Ireland (EirGrid 2012)





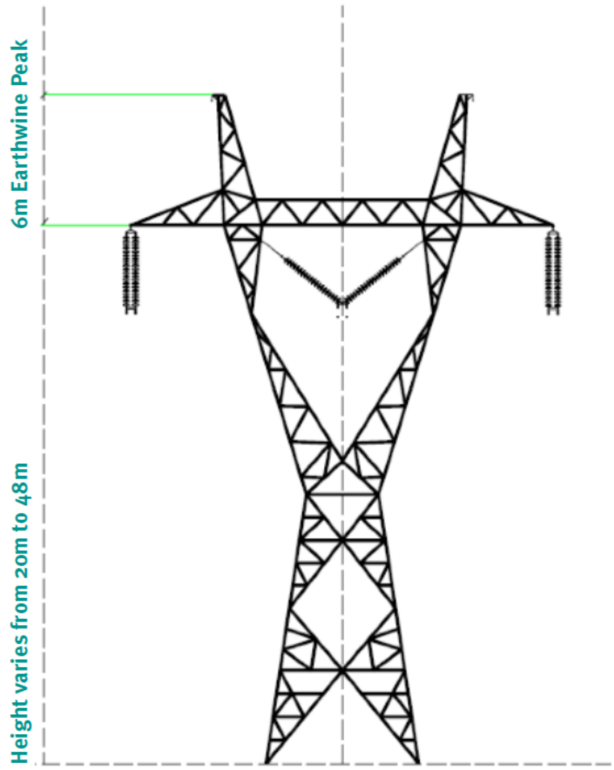
220kV Intermediate Tower
(Typical Dimensions)

Number of Foundations = 4

Leg Spacing = 6.3m

Foundation Depth = 3m

Foundation Width = 2.5m x 2.5m



400kV Intermediate Tower
(Typical Dimensions)

Number of Foundations = 4

Leg Spacing = 7.6m

Foundation Width = 4.6m x 4.6m

3 LITERATURE REVIEW: DISPLACEMENT AND ELECTRO-MAGNETIC EFFECTS ON BIRDS

3.1 INTRODUCTION

This section considers other potential impacts of the construction and operation of transmission lines on birds. These impacts are unlikely to cause direct and immediate mortality in the same way as collision and electrocution, but may have more subtle, indirect effects on a particular population through reduced productivity, population size and/or survival.

The construction of power lines may result in temporary and localised disturbance to birds from construction activities (e.g. through noise) and the presence of construction workers and machinery. Habitat clearance may be required which may result in the loss and/or fragmentation of habitats. These impacts are likely to be similar to but of lesser magnitude in duration and extent to those caused by other linear man-made features such as roads, and are not considered in detail here.

Habitat clearance during the breeding season has the potential to disturb nesting birds and destroy nests, eggs and chicks. Under the Wildlife Act 1976 (as amended), it is an offence to remove or destroy eggs and nests or wilfully disturb birds near a nest. Construction activities during the breeding season will need to be carried out in such a way as to avoid disturbance to breeding birds.

During operation, birds may avoid areas in the vicinity of transmission lines. This may result from alteration of habitat so it is less suitable for birds, for example by reducing the availability of nesting, foraging habitat or by increasing predation risk. Electromagnetic fields (EMFs) or noise generated by the conductors might cause disturbance and exposure to EMFs might affect avian physiology.

3.2 DISPLACEMENT / EXCLUSION

Relatively little published information is available on the avoidance of power lines by birds. A study of the impact of wind farm infrastructure on birds in the UK looked at the avoidance of turbines, tracks and transmission lines for a sample of upland species including raptors, waders and passerines (Pearce-Higgins *et al.,* 2009). Compared with wind turbines, birds showed a smaller degree of avoidance of tracks and no consistent avoidance of transmission lines. Significant effects of power lines were identified only for passerines, with stonechats showing weak avoidance whereas Wheatear and Skylark were more likely to be detected close to power lines. For Skylark, Pearce-Higgins *et al.* (2009) also cite a further study showing avoidance of overhead transmission lines (Milsom *et al.,* 2001). Prinsen *et al.* (2011a) cite two studies in cultivated grasslands in northern Europe; one found lower densities of breeding waders, except Oystercatcher within 100m of power lines; a second study showed no impact on lapwing and curlew but a lower density of singing male skylarks within 100m of power lines. Grazing densities of wintering White-fronted and Bean Geese were found to increase with distance to power lines of low height, with significantly reduced grazing levels within 40-80m, although no effect was found in an area next to the river Rhine where wires were at a height of 60m (Balassus and Sossinka, 1997). In general, wintering geese prefer to forage in areas with an open view and will also avoid other manmade landscape features such as roads, hedges, forest plantations, settlements and wind turbines (Larsen and Madsen, 2000). Avoidance distances of 50m from power lines are reported for pink-footed geese, one of the most wary geese species in relation to human activity (Larsen and Madsen, 2000); although the same species has been found to habituate to wind farms in Denmark (Madsen and Boertmann, 2008).

Pruett e*t al*. (2009) used radio-telemetry to track the movements of two grouse species, Lesser Prairie-chicken (*Tympanuchus pallidicintrus*) and Greater Prairie-chicken (*T. cupido*) at two locations in Oklahoma, USA, over seven and three year periods respectively. Both species are dependent on large tracts of unfragmented grassland habitat. They reported that both species avoided power lines by at least 100m. Lesser Prairie-chickens crossed transmission lines less often than would be expected if their movements were random and their home ranges overlapped power lines less often than would be expected. Modelling indicated that transmission power lines were significantly avoided by the little bustard *Tetrax tetrax* in Southern Portugal (Silva *et al.,* 2010). The distance to power lines was found to be the most important factor determining breeding densities in sites with suitable habitat for the species, raising the possibility that the presence of power lines may have a population effect on this threatened bird species.

Bird species which inhabit open environments might show avoidance of tall structures such as overhead power lines (this could result from avoidance of pylons or poles and/ or the wires) because of perceived predation risk. For example raptors and other predatory birds perch on tall objects to survey hunting areas (Pruett e*t al*., 2009; Hagen and Giesen, 2005; Shroeber and Robb, 1993).

It has also been suggested that avoidance of power lines by birds and some mammals may be caused by discharges of ultraviolet light, so that power lines appear as lines of flickering light (Tyler *et al.,* 2014).

In some cases it is possible that findings of apparent displacement may not result from direct causal relationships between the presence of the power lines and bird avoidance, but may be due to factors such as habitat variation associated with proximity to power lines. Where a transmission line passes through a forest, a swathe of trees is usually removed from beneath the line. This results in a habitat change and a resultant change in the composition of the bird community in the immediate vicinity of the power line.

In an Irish context, open environments include marshes and other wetlands; bogs and heaths, and grasslands. In Ireland, key ground-nesting bird species that utilise such habitats, might avoid tall structures such as overhead power lines (pylons/poles and/or overhead wires), and are reasonably widely distributed. These are Red Grouse, Lapwing, Golden Plover, Ringed Plover (primarily coastal), Oystercatcher (primarily coastal), Redshank, Dunlin, Common Snipe, Curlew, Sandwich Tern (coastal), Common Tern (primarily coastal), Arctic Tern (primarily coastal), Little Tern (coastal), Skylark, Meadow Pipit, Rock Pipit (coastal), Whinchat and Wheatear. Outside the breeding season, a wider range of birds utilise such open habitats and might also be expected to show avoidance behaviour, including wintering waders, geese and other wildfowl and wetland species, and other passerine species such as larks and pipits and some finches and buntings.

Construction of new transmission lines in Ireland may have some limited effects in reducing the density of breeding birds or limiting the use of areas close to power lines by foraging birds such as wintering geese. No studies have been found that suggest wide scale impacts displacement effects that might affect any species at a population scale. Nevertheless it is recommended that consideration is given to potential impacts should transmission power lines be proposed in areas which are important for wintering geese, in particular Greenland White-fronted Geese (*Anser albifrons flavirostris*) which show high site fidelity in wintering areas (Wilson *et al.,* 1991).

3.3 ELECTRIC AND MAGNETIC FIELDS

Power lines generate EMFs. There is limited evidence that exposure to EMF may affect the cellular, endocrine, immune and reproductive systems of vertebrates. Very few quantitative studies have been carried out (Prinsen *et al.*, 2011a) and there is only one major review paper in relation to birds and EMF (Fernie and Reynolds, (2005).

In general, birds spend little time in close proximity to power lines and are likely to sustain limited exposure to EMF. However bird species which nest on power line support structures such as pylons – mainly raptors and storks - may be exposed for long periods during a breeding season and over repeated seasons. A review of the effects of EMF exposure on birds considered behaviour, reproductive success, growth and development, physiology, endocrine and immune function, and oxidative stress (Fernie and Reynolds, 2005). A limited number of studies on birds have been carried out in field and laboratory situations, involving a range of species including raptors, passerines and chickens. These have found a range of effects with generally negative implications for reproduction and development. However, the reproductive success of a number of wild bird species nesting on or close to power lines does not seem to be compromised by exposure to EMF in the short term, and in some cases birds nesting on power lines have higher reproductive success than their counterparts elsewhere (e.g. ospreys nesting on power lines in Germany) (Fernie & Reynolds, 2005; Dell'Omo *et al.*, 2009).

In relation to the development of the transmission system in Ireland, there is no evidence to suggest that EMF exposure is likely to represent a concern for birds. Although birds – mainly corvids – do make use of pylons for nesting in Ireland, most species are likely to sustain very little exposure.

4 FIELD STUDY OF BIRD MORTALITY AT POWER LINES IN IRELAND: WIDE-SCALE ASSESSMENT OF COLLISION RATES

4.1 INTRODUCTION

Chapters 4 and 5 describe field studies of mortality risk for birds at transmission power lines in Ireland carried out by RPS.

Studies were designed in accordance with the overall aims of the evidence-based environmental studies commissioned by EirGrid, to establish the impacts of existing 110kV, 220kV and 400 kV power lines on birds by surveying and assessing sections of existing transmission lines. In 2012 and 2013 a wide-scale assessment of collision risk was carried out involving searches for bird remains under transmission power lines at a large number of sites throughout the Republic of Ireland (RoI). Study sites were divided into low risk and high risk, in terms of bird collisions, based on the findings of the literature review. The results of this study are reported in this chapter. This was followed by a more intensive study at a small number of sites identified as potentially high risk for bird collisions (reported in Chapter 5). This involved weekly searches for bird remains under transmission power lines to estimate collision rates in areas with relatively large populations of potentially vulnerable bird species. These searches were combined with observations of flight activity to provide an insight into the numbers and behaviour of birds crossing power lines at study sites.

4.2 METHODS

The specific aim of the bird collision studies was to survey sections of existing transmission power line in Ireland for evidence of bird casualties from collision with wires and to generate estimates of collision rates which could be compared with published results from other studies. The risk of electrocution in Ireland is extremely low, so the main cause of power line deaths would be collision (Section 2.2.3).

The literature review of bird collisions at power lines indicated that the risk of collision for birds is likely to vary depending on the location of power lines in relation to bird habitats and areas where birds tend to concentrate, and the orientation and design of power lines. The power line sites identified for survey were divided into low and high risk sites, based on the characteristics of sites where bird collisions were likely to be more prevalent (Section 2.2). The aim was to quantify risk at areas likely to be most sensitive for birds of conservation concern and to compare these sites with areas considered to be of lower sensitivity.

4.2.1 Site Selection

4.2.1.1 High Risk Sites

Factors potentially associated with a higher risk of bird collision with power lines include the presence of water bodies, river valleys, and concentrations of birds (Section 2.2). In accordance with these, a series of high risk sites were identified where transmission power lines cross major rivers. Proximity to Special Protection Areas (SPAs) classified for rare and migratory bird species (EU Birds Directive 2009/147/EC) was also considered.

High risk sites were as follows:

- Shannon Bridge,
- Clonony More,
- Fermoy,
- Kilkenny,
- Waterford.

The locations of these sites are shown in Figure 3 and Figures 4 to 8 show the areas of transmission power line surveyed at each site. Field surveys of the high risk sites were carried out between 3 March and 3 May 2013. Surveys were timed to coincide with the late winter and early spring seasons when the large numbers of migratory wetland birds are likely to be present in these areas. These waterfowl include species of geese, swans, ducks and waders which overwinter in wetland and coastal areas and undertake passage migrations to and from breeding areas mainly during the spring (March and April) and autumn (August to October) passage periods.

BirdWatch Ireland (BWI) was consulted over the proposed study and asked to provide views on high risk situations or locations in Ireland. BWI indicated that they did not have specific information on sites within the RoI where bird collisions with power lines were considered a conservation issue. They commented on the bird species that would be of greatest concern in relation to power lines – namely the qualifying species of SPAs (EU Birds Directive). Four of the five high risk sites were in close proximity to SPAs. Details of these SPAs and qualifying bird species are included in Table 1 below.

Table 1: High risk transmission power line sites and SPAs

High Risk Site	SPA (site code)	Proximity to SPA	Qualifying Bird Species[1]	Season[2]
Fermoy	Blackwater Callows (004094)	Survey area within SPA boundary	Whooper swan Wigeon Teal Black-tailed godwit	W W W W
Shannon Bridge	River Suck Callows (004097)	Survey area within SPA boundary	Whooper swan Wigeon Golden plover Lapwing	W W W W

High Risk Site	SPA (site code)	Proximity to SPA	Qualifying Bird Species[1]	Season[2]
			Greenland White-fronted goose	W
	Middle Shannon Callows (004096)	Survey area within SPA boundary	Whooper swan Wigeon Corncrake Golden plover Lapwing Black-tailed godwit Black-headed gull	W W B W W W,B W
Clonony More	Middle Shannon Callows (004096)	Survey area 1-2km from SPA boundary	As above	
Kilkenny	River Nore (Site Code 004233)	Survey area adjacent to SPA boundary	Kingfisher	B
Waterford	No SPA[3]			

1. Based on features of interest listed on the website of the National Parks and Wildlife Service, Ireland http://www.npws.ie/protectedsites/specialprotectionareasspa/. In addition to the qualifying features, the SPA synopses, included on the website, indicate that sites support assemblages of wetland birds throughout the year.
2. W = wintering, B= breeding.
3. The site is adjacent to the Blackwater River SAC. The SAC synopsis (NPWS, 2007) indicates that an assemblage of wetland birds – including the species listed above for other SPAs (except corncrake) - use the river throughout the year.

4.2.1.2 Low Risk Sites

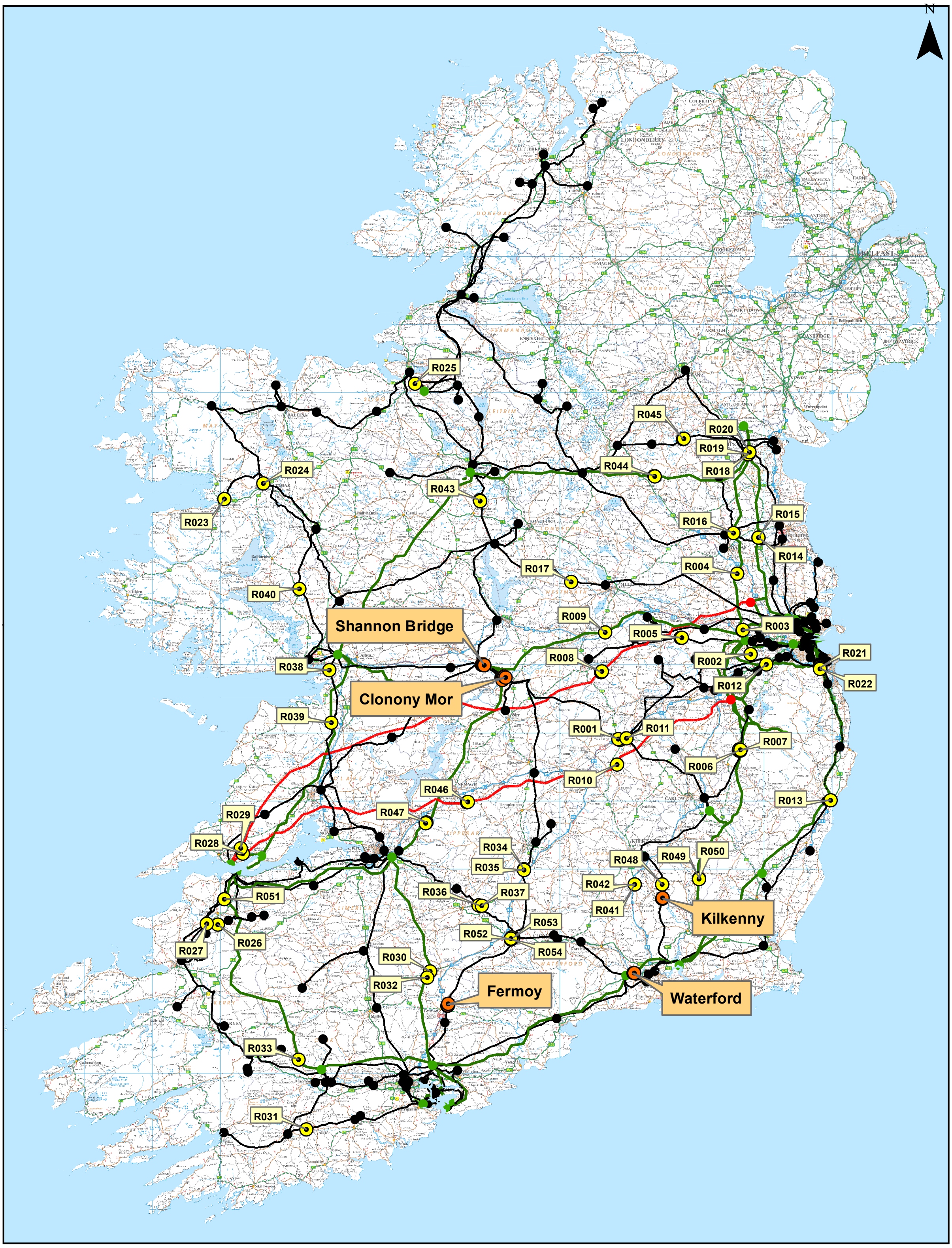
These were selected to be broadly representative of the wider countryside areas in which power lines occur, to be 'neutral' in terms of any known risk factor for bird collisions, and to be widely distributed throughout the RoI. Sites were identified from aerial photographs and maps primarily on the basis that (i) there were overhead power transmission lines (110kV, 220kV or 400kV) present, (ii) the location was relatively easily accessible and, (iii) the habitat and ground conditions made it possible to search for corpses with a degree of confidence that a similar proportion of those present could be found across sites (see 4.2.1.3 below), and (iv) they did not fall under the criteria used to identify high risk sites (presence of water bodies, river valleys and SPAs).

A total of 54 sites were surveyed between 7 March 2012 and 8 January 2013. The locations of these sites are shown in Figure 3.

4.2.1.3 Habitat Selection for High and Low Risk Sites

All study sites in both categories were selected only where habitat and ground conditions made it possible to search for corpses with a degree of confidence that a similar proportion of those present could be found across sites. Thus habitats such as woodland and scrub, wetlands, water bodies, and others, where corpses would be extremely difficult to locate, directly underneath power lines, were avoided; although study sites could be in close proximity to such habitats. This approach to minimising the effect of habitat variation on the ability of observers to detect bird corpses between different study sites is recommended by Barrientos *et al.* (2011) on the basis of a meta-analysis of surveys of bird collision rates with power lines. It is acknowledged, however, that there are risks in terms of searches being carried out in areas that are not representative of the wider habitat through which the power lines pass. This is particularly the case for high risk sites, where the presence of waterbodies and wetland habitats was a criteria for site selection, but it was not possible to locate search areas directly over waterbodies or wetland habitats with tall vegetation because of the difficulty of searching for corpses. The habitats present within the Irish study sites were pasture, arable land, open ground/scrub and bog. Access permission was required from landowners for surveys, and areas where access permission was unlikely to be available, such as private domestic dwellings, industrial locations, and some areas of agricultural land, were also avoided. Thus the availability of suitable searching habitat and access permission limited the length of power line that could be surveyed at each site.

Figure 3: Location of Transmission Power Line Study Sites 2012/2013



Title **Figure 3** **Location of Transmission Power Line Survey Sites 2012/2013**

Legend

High Risk Sites	110kV Station	110kV Network
Low Risk Sites	220kV Station	220kV Network
	400kV Station	400kV Network

Project: EirGrid - Evidence Based Guideline Studies

Client: EIRGRID

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Date:	31/07/2014		

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2. All levels are referred to Ordnance Datum, Malin Head.
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Figure 4: High Risk Sites 2013, Fermoy

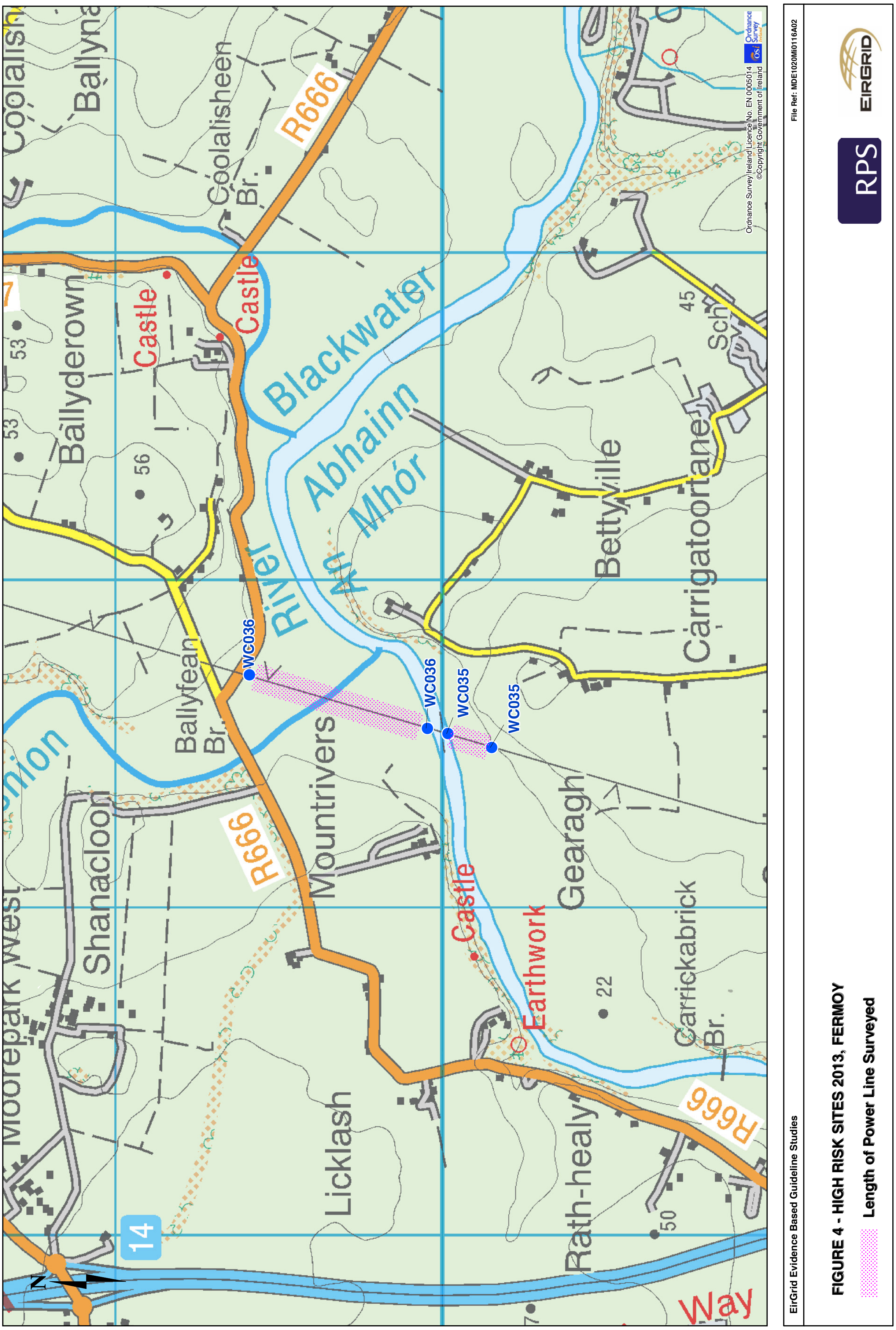


Figure 5: High Risk Sites 2013, Shannon Bridge

Figure 6: High Risk Sites 2013, Waterford

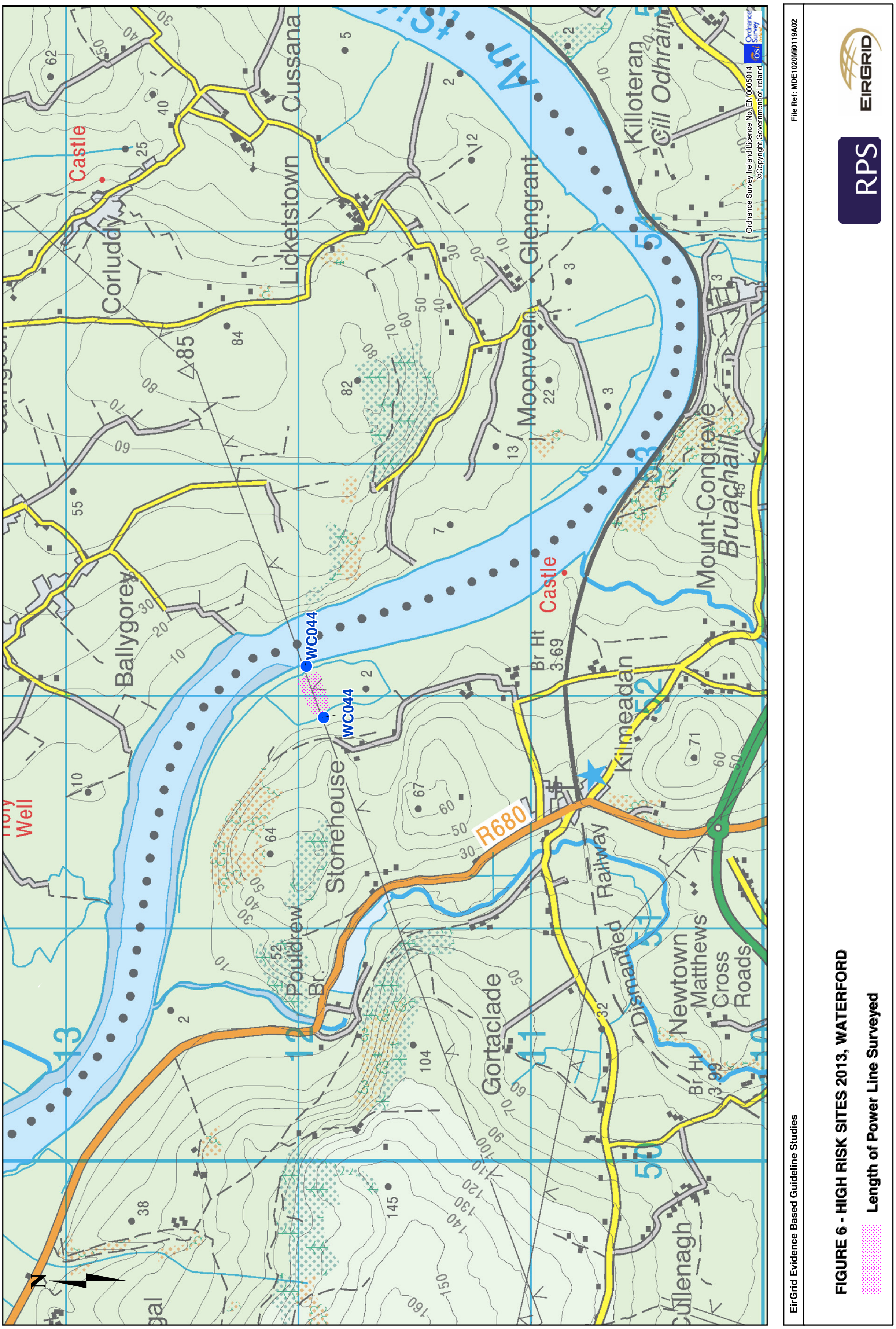


Figure 7: High Risk Sites 2013, Kilkenny

Figure 8: High Risk Sites 2013, Clonony More

4.2.2 Field Methods

To investigate the incidence of mortality of birds through collision with overhead power lines, searches for bird corpses were undertaken beneath power lines. Field methods for corpse searches were devised with reference to methods used in similar published and unpublished studies and reviews (e.g. Shaw *et al.,* 2012; Barrientos *et al.,* 2011; Frost, 2008; Rubolini *et al.,* 2005, MBEC, 2005; Bevanger, 1999). The same search methods were used at high risk and low risk sites.

There was no fixed length of power line transect, as this varied according to the habitat and the accessible length available at any given location. Start and end points were mapped. Each power line survey site was divided into land parcels (based on land ownership) and a separate recording form was completed for each land parcel (for high risk sites, land parcels are shown and numbered separately on Figures 4 to 8). The total length of power line surveyed at each land parcel and the height of the power line above the ground were measured using a rangefinder. The total length of power line surveyed at high risk sites varied from 213–1985m (mean 946m), and between 90–700m (mean 260m) at low risk sites.

The ground beneath the defined sections of overhead power lines was searched for bird corpses (or of signs indicative of a corpse). The area within a 45º fall angle from the power line (from the outermost cable on either side) was searched for bird casualties, so that the width of the search area either side of the power lines was the same as the maximum height of the wires. This gave search areas of between 26–86m at high risk and 22–80m in width at low risk sites, according to the height of power line.

In each search area, the centreline was walked first and then areas either side, searching for bird remains. When the end of the land parcel was reached, based upon the ease with which the land parcel could be searched, the distance out from the centreline to be used for the second (return) traverse (and subsequent traverses) was determined. This did not exceed 10m but was reduced from 10m where the habitat or land was considered difficult to search (e.g. taller vegetation). Hence, traverses were a maximum of 10m apart and the observer walked within at least 5m of all points.

The location of bird remains found - distance along the power line from the start of the survey and distance from the centre line – was measured using a range finder. A description of all bird remains was entered on the recording form. A digital photograph was taken and remains were collected in sealed bags for all high risk sites and for low risk sites where identification was uncertain. Bird remains were identified to species level as far as possible by reference to published identification guides.

Bird remains were categorised as follows:

i. Intact: the carcass is completely intact, not badly decomposed, and showing little or no sign of having been fed upon by a predator or scavenger.

ii. Scavenged: carcass which is to some degree dismembered and shows signs of having been fed upon by a predator or scavenger (from minor scavenging to heavily scavenged but some tissue, bones, flesh and feathers present).

iii. Feather spot: consists of ten or more feathers, or two flight feathers (i.e. primaries, secondaries or tertials from the wing; or tail feathers) at one location.

iv. Feathers: for all other records of less than 10 feathers, other than single downy or body feathers, i.e. groups of between two and ten feathers, not more than one of which is a flight feather.

All bird remains were assessed for the possibility that collision, electrocution when perching (rather than collision) or another cause (e.g., shot, predated) was responsible for their mortality. For the purposes of data analysis, it was assumed that all bird remains found during power line searches were collision mortalities unless there was clear evidence to the contrary, and only intact and scavenged carcasses and feather spots (categories i to iii above) were counted as casualties. Records of less than 10 feathers (or 2 flight feathers) were not considered to be definitive proof of a bird corpse, as it is possible that feathers could have been lost during activities such as preening, moulting or fighting.

The criteria for classifying bird remains are similar to those described in other studies of bird casualties at power lines and wind farms (e.g. Barrientos *et al.*, 2011; MBEC, 2005; Johnson *et al.*, 2002; Committee on Environmental Impacts of Wind Energy projects etc., 2007), although in many studies detailed descriptions of any criteria used to classify carcasses and to include/exclude remains from consideration are not provided; where details are provided, there are some variations between studies e.g. in the minimum number of feathers used to identify a feather spot.

Notes on habitats and vegetation and other relevant information (e.g. anecdotal observations of birds flying across power lines at study sites, or information provided by landowners) were also included on recording forms.

4.2.2.1 Number of Site Visits

Three corpse search visits were made to each high risk site, with a gap of at least 10 days between visits. Low risk sites were visited on one occasion only. Field surveys were undertaken by suitably qualified surveyors.

4.2.2.2 Investigation of Scavenger Removal and Observer Search Efficiency Bias

Studies of scavenger removal rates and observer search efficiency were originally proposed to accompany the corpse searches at transmission power line sites in the RoI. However it was not possible to complete these because of concerns about the public relations implications of asking landowners for permission to lay out bird corpses on private land. The possibility of using Electricity Supply Board (ESB) lands for scavenger removal and observer efficiency studies was investigated. However the available areas were far removed from the power line sites identified for corpse searches. Scavenger removal rates vary greatly between areas due to variation in local assemblages and density of predatory animals (see Section 2.2.5.1). Thus ideally scavenger removal experiments should be carried out in areas close to power line survey sites and rates from distant sites may not be applicable. In a study covering a large number of sites throughout the RoI (Figure 3), application of scavenger removal rates from a small number of sites would be likely to introduce unknown errors into any adjusted collision rates.

4.2.2.3 Data Analyses

Data from high risk sites were entered into an access database for analysis. For low risk sites, data were entered into an excel spreadsheet for analysis.

4.3 RESULTS

All collision rates for birds at transmission power lines presented below are uncorrected for the effects of scavenger removal, observer efficiency and crippling bias (see Section 4.2.2.2).

As noted in the methods, it was assumed that all bird remains found during field surveys were a result of power line deaths, unless there was clear evidence to the contrary. The literature review indicated that because of the wide spacing of conducting wires, electrocution was unlikely to be a risk for birds at transmission power lines in Ireland (Section 2.3), and no obvious signs of electrocution such as scorched feathers were found during field surveys, thus collision is considered to be the most likely cause of power line deaths. Few intact carcasses were found and the majority of remains were feather spots, which provide very little or no information on the cause of death. A list of casualties is included in Appendix B. At high risk sites 35 bird remains were found (excluding one feather spot at Kilkenny see 4.3.1), comprising 26 (74%) feather spots, seven (20%) scavenged carcasses and two (6%) intact carcasses. At low risk sites there were 44 bird remains (excluding one feather spot found outside the search area), comprising 31 (70%) feather spots and 13 (30%) scavenged carcasses.

4.3.1 High Risk Sites

A summary of the estimated collision rates of birds at high risk sites is given in Table 2.

Field visits revealed that bird diverters had been installed on the power lines at Kilkenny. Results for Kilkenny are therefore not included in the mean for high risk sites. The presence of bird diverters was not known at the time of site selection. The landowner commented that swans used to fly into the line until bird deterrents were installed and that none had been recorded since. The surveyor reported that the bird diverters fitted at Kilkenny were small ball-like devices fitted at fairly regular intervals – indicating they were marker spheres (Figure1c).

The length of transmission line surveyed at the five sites varied from 213m to 1,985m. The total length of power line surveyed at all high risk sites was 4,729m. The habitats comprised agricultural grassland, wet grassland, marsh, tall herb, swamp and arable.

The mean number of bird casualties per km varied from 0.83 to 7.74. Rates of bird casualties per km per day varied from 0 to 0.49; equivalent to between 0 and 178.58 casualties per km per year (assuming no variation in the rate of bird collisions throughout the year).

For high risk sites combined (excluding Kilkenny), the mean casualties per km was 3.91 (± 1.62; S.E.) (6.39 (± 3.57; S.E.) based on the first visit only – for comparison with low risk sites where only one visit was made); the mean casualties per km per day was 0.16 (± 0.11; S.E.), equivalent to 57.11 per year.

Table 2: Summary bird collision data from high risk transmission power line sites

Site	Length of power line surveyed / m	Visit no.	Date	No. bird casualties	Casualties per km power line	Casualties per km per day[1]	Casualties per km per year[2]
Fermoy	732	1	06/03/2013	5	6.83	N/A	N/A
		2	21/03/2013	6	8.20	0.55	199.59
		3	09/04/2013	6	8.20	0.43	157.57
				Mean	7.74	0.49	178.58
Shannon Bridge	1,985	1	08/03/2013	5	2.52	N/A	N/A
		2	03/04/2013	4	2.02	0.08	28.31
		3	15/04/2013	1	0.50	0.04	15.33
				Mean	1.68	0.06	21.82
Kilkenny[3]	213	1	11/03/2013	0	0	N/A	N/A
		2	27/03/2013	1	4.69	0.29	0.11
		3	03/05/2013	0	0	0	0
				Mean	1.56	0.15	0.05
Waterford	185	1	11/03/2013	3	16.22	N/A	N/A
		2	27/03/2013	0	0	0	0
		3	12/04/2013	0	0	0	0
				Mean	5.41	0	0
Clonony More	1,614	1	15/03/2013	0	0	N/A	N/A
		2	05/04/2013	1	0.62	0.03	10.78
		3	20/04/2013	3	1.86	0.12	45.26
				Mean	0.83	0.08	28.02

Notes
1. Calculated for visits 2 and 3 only based on the number of casualties and days since the previous visit.
2. Calculated from the mean rate per day from visits 2 and 3 multiplied by 365.25
3. Excluded from means as bird deterrents were fitted to wires

The species composition of casualties at high risk sites is shown in Figure 9. Most records were corvids (corvid spp. and magpie) and pigeon species (woodpigeon and feral pigeon). No SPA qualifying species (see Table 1) were found. Waterfowl species comprised 6 ducks (4 mallard and 2 unidentified) and 2 snipe. A list of all casualty records is included in Appendix B.

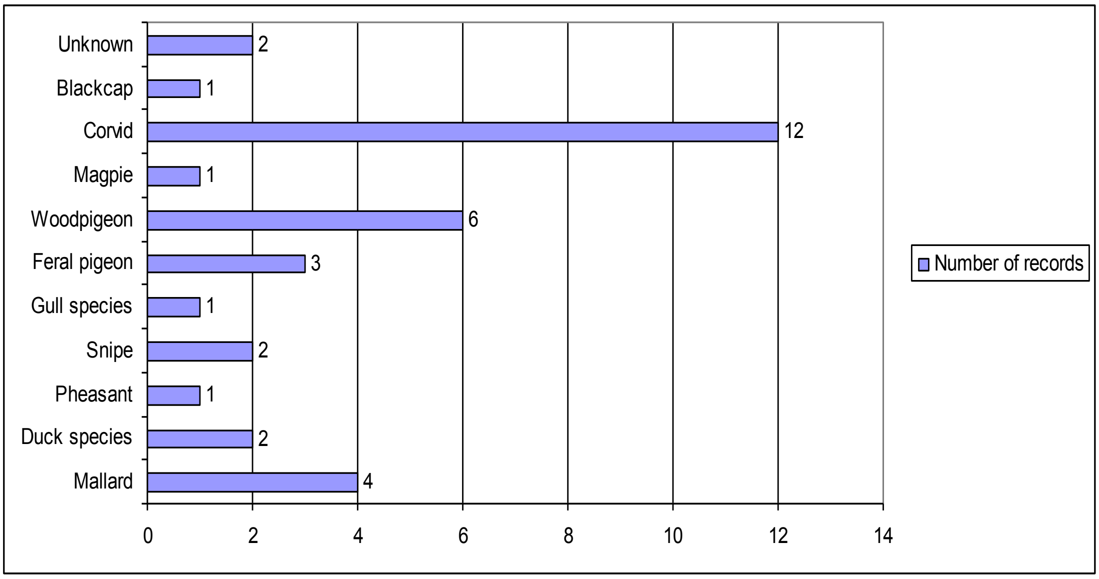


Figure 9: Species composition of bird casualties at high risk transmission power line sites

4.3.2 Low Risk Sites

Collision rates estimated from searches for bird remains at low risk sites are summarised in Table 3. The length of transmission power line surveyed at individual sites varied between 90m and 700m. The total length surveyed at all sites was 14.043 km. The habitats at low risk sites comprised pasture, arable, bog and scrub/bare ground.

The number of bird remains recorded varied from 0 to 44.44 per km. As only one visit was made to each site it is not possible to calculate casualties per unit time, as was done for the high risk sites. The mean bird casualties per km for all low risk sites was 3.36 (± 0.89; S.E.), compared with the equivalent mean for all high risk sites (based on the first visit only to high risk sites, as only one visit was made to all low risk sites) of 6.39 (± 3.57; S.E) casualties per km.

Table 3: Summary bird collision data from low risk power line sites

Site	Length of power line surveyed / m	Date	No. bird casualties	Casualties per km power line
R001 Portlaoise	437	07/03/2012	3	6.86
R002 Reeves Castle	700	22/03/2012	6	8.57
R003 Maynooth	240	02/04/2012	2	8.33
R004 Ringlestown	173	01/05/2012	0	0.00
R005 Carbury	320	03/05/2012	2	6.25
R006 Castleruddery a	503	04/05/2012	0	0.00
R007 Castleruddery b	329	04/05/2012	1	3.04
R008 Anagharvey	429	08/05/2012	0	0.00
R009 Tyreallspass	251	08/05/2012	1	3.98
R010 Ballyroan	514	09/05/2012	2	3.89
R011 Ballymooney	214	09/05/2012	1	4.67

Site	Length of power line surveyed / m	Date	No. bird casualties	Casualties per km power line
R012 Rathcoole	207	13/06/2012	0	0.00
R013 Shelton Abbey	194	25/06/2012	1	5.15
R014 Kilbride	266	25/06/2012	2	7.52
R015 Roosnaree	208	26/06/2012	1	4.81
R016 Rathkenny	231	26/06/2012	1	4.33
R017 Kilpatrick	216	27/06/2012	0	0.00
R018 Monavallett Goran	152	07/07/2012	0	0.00
R019 Monavallett Flagford	162	07/07/2012	0	0.00
R020 Monavallett Drybridge	250	07/07/2012	1	4.00
R021 Carrickmines, Fassaroe	194	12/07/2012	0	0.00
R022 Carrickmines, Ballybeg	214	12/07/2012	1	4.67
R023 Westport	159	25/07/2012	1	6.29
R024 Castlebar	154	26/07/2012	0	0.00
R025 Ballintogher	272	26/07/2012	0	0.00
R026 Furhane	259	04/09/2012	0	0.00
R027 Irramore	215	04/09/2012	1	4.65
R028 Ballycurran	190	06/09/2012	0	0.00
R029 Knocknahoon	182	06/09/2012	1	5.49
R030 Killee	254	28/08/2012	0	0.00
R031 Caher	255	30/08/2012	0	0.00
R032 Ballindangan	265	28/08/2012	0	0.00
R033 Carrigonirtane	138	30/08/2012	2	14.49
R034 Aughnagamun a	240	23/11/2012	0	0.00
R035 Aughnagamun b	356	23/11/2012	4	8.43
R036 Kilfeakle a	197	30/11/2012	0	0.00
R037 Kilfeakle b	225	23/11/2012	0	0.00
R038 Sulfay, Oranmore	248	11/12/2012	0	0.00
R039 Cappanahisha S	280	11/12/2012	0	0.00
R040 Tonacooleen	193	12/12/2012	0	0.00
R041 Derreen	470	12/12/2012	2	4.26
R042 Carrowgobbadagh	313	17/12/2012	1	3.19
R043 Rattinagh	187	17/12/2012	0	0.00
R044 Termon Upper	133	03/01/2013	0	0.00
R045 Corgreagh	292	03/01/2013	0	0.00
R046 Ballyvanran	232	08/01/2013	0	0.00
R047 Controversy	234	08/01/2013	1	4.27
R048 Cloghscregg	283	04/12/2012	0	0.00
R049 Mohullen a	90	04/12/2012	4	44.44
R050 Mohullen b	157	04/12/2012	1	6.37
R051 Pollagh	305	07/12/2012	0	0.00
R052 Pollagh Coil	191	07/12/2012	0	0.00
R053 Knockmorris	388	28/11/2012	0	0.00
R054 Monaraha	282	30/11/2012	1	3.55

The species composition of casualties at low risk sites is shown in Figure 10. As for high risk sites, the majority of records were corvids (corvid spp., rook and magpie) and pigeon species (pigeon spp., woodpigeon and feral pigeon). Only three waterfowl species were found (single records of snipe, lapwing and tufted duck) and one passerine species (blackbird). A list of all casualty records is included in Appendix B.

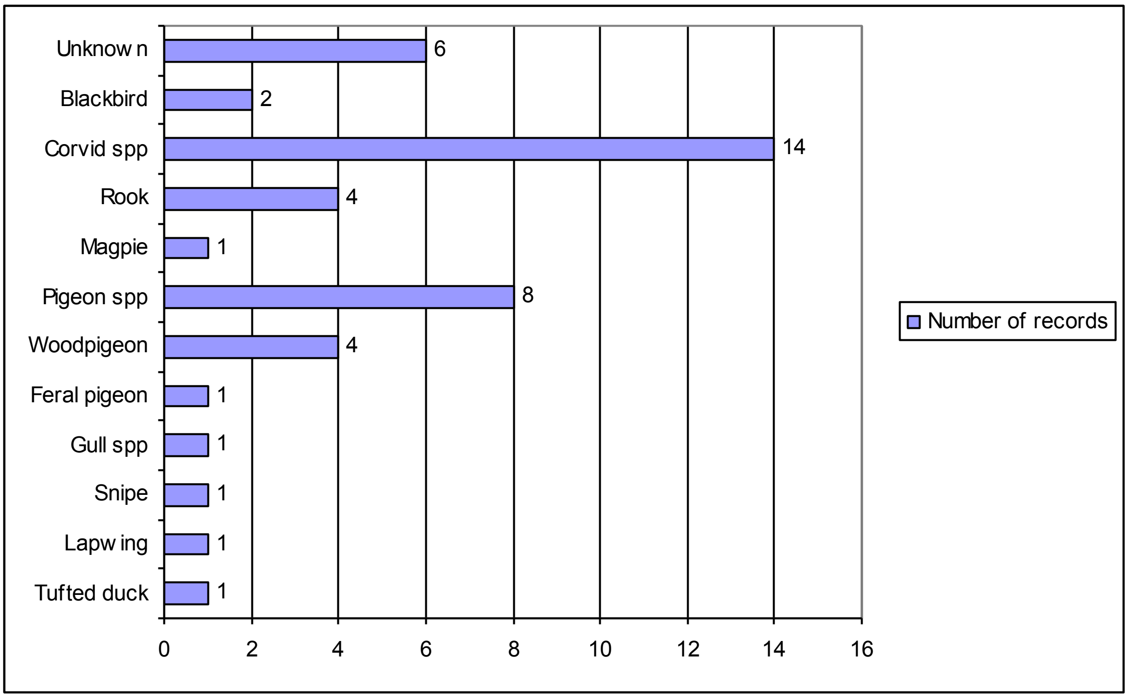


Figure 10: Species composition of bird casualties at low risk transmission power line sites

4.4 DISCUSSION

4.4.1 Previous evidence for bird collisions with Transmission Power Lines in Ireland

Consultation with BWI and a search of published scientific papers, grey literature and the internet did not identify any sites in the RoI where bird collisions with transmission power lines has been highlighted as an issue – either in terms of bird conservation or damage to power lines. One of the high risk sites selected for the field study, at Kilkenny, was found to have bird diverters fitted to the power lines. The landowner here reported that swans used to fly into the line until bird deterrents were installed and that none had been recorded since. Thus in at least one area of the RoI, bird collisions with power lines had been identified as a problem and mitigation carried out, by fitting bird diverters to the wires. In the Inishowen area, the Electricity Supply Board (ESB) has fitted markers to power lines (presumably distribution lines) to prevent Whooper Swan collisions which were causing power cuts (Donegal News, 2012). In Northern Ireland, bird diverters have recently been fitted to power lines close to the Foyle Basin to mitigate Whooper Swan collisions in this area (Power Northern Ireland, 2013).

4.4.2 Estimated collision rates from field surveys in Ireland and comparison with other studies

The collision rates resulting from transmission power line searches in the RoI have been presented without correction for potential biases resulting from scavenger removal, observer search efficiency or crippling. Rioux *et al.* (2013) reviewed a range of power line collision studies and found that removal rates (for medium-sized to large birds, excluding small birds) by scavengers were highly variable and averaged 39%; whereas observer search efficiency averaged 80% (again for medium-sized to large birds) with little variation. On the basis of a few studies that have attempted to measure crippling bias the average is 80% with low variability; if this is more widely applicable then crippling rates could have a strong effect in terms of increasing estimates of power line mortality rates from corpse search studies (Rioux *et al.,* 2013).

Due to the known biases, and variation between sites (which may be most marked in relation to scavenger removal rates, Rioux *et al.*, 2013), the calculation of true collision (and electrocution) rates at power lines and therefore comparison between sites and studies is very difficult to achieve (Rubolini *et al.*, 2005, Bevanger, 1999). Other factors, such as the width of transects (area searched either side of a power line) also vary between studies and may affect the potential for finding bird remains and the comparability of results.

Collision rates for birds and power lines in the scientific literature are usually reported as rates per km power line per year. Estimated collision rates from a range of studies vary from about 0.1 to 489 casualties per km per year (Jenkins *et al.*, 2010, Drewitt & Langston, 2008; this range appears to include studies which have been corrected for the various biases which have been discussed as well as uncorrected estimates).

Uncorrected collision rates measured over a period of approximately 2 months at five transmission power line sites (the high risk sites) in the RoI varied from 0 to 0.49 birds per km per day (Table 2), equivalent to rates of 0 to 179 casualties per km per year, broadly falling within the range reported in other studies. Based on a review of studies of bird collisions at power lines, Rioux et al. (2013) concluded that accounting for scavenger losses and bird remains missed by observers is likely to increase uncorrected collision rates by a factor of 2. Further, accounting for a crippling bias, to account for birds which hit wires but are able to fly or walk away from the search area for bird remains, could increase estimates by a factor of 10.

Depending on the timescale over which studies of collision mortality are carried out, focusing on periods of highest flight activity for birds is a potential source of bias in the opposite direction to scavenger removal bias, observer search efficiency and crippling bias, in terms of estimating true annual mortality rates and comparisons between sites and studies. Surveys at the high risk sites in the RoI were carried out between early March and early May 2013, timed to coincide with the spring passage migration period for waterbirds. Studies of short duration which focus on the most active periods for birds may overestimate annual mortality rates (Rioux *et al.*, 2013) as they do not include periods when mortality is likely to be lower (e.g. when concentrations of passage and wintering waterfowl are absent).,Few studies have been found which investigate variation in bird collision rates with power lines at different times of year.

Many studies of bird collision rates at power lines focus on short areas of power line where collisions have been identified as an issue. Two recent examples of studies which involved power line surveys over more extensive areas within a geographical region are provided by Rubolini *et al.* (2005) for Italy and Shaw *et al.* (2010) for the Overberg Region of South Africa. For five sites in Italy the estimated mortality rate from collisions (birds per km per year, uncorrected for any bias) varied from 0 to 86.9. In the Overberg, South Africa, the overall mortality rate (also uncorrected for bias) from surveys of 199 km of power line was 0.206 birds per km per year (results were not reported separately for individual survey sites). The majority of deaths (97 %) were attributed to collision and the remainder to electrocution. The South African study also compared death rates between transmission and distribution lines and reported that the number of carcasses found during surveys was twice as high on transmission lines.

For the field study in the RoI, low and high risk transmission power line sites, in terms of bird collisions, were selected *a priori* based on information on the characteristics of sites which tend to be associated with higher rates of bird collision. The expectation was that estimates of bird collisions per km at high risk sites would exceed those at low risk sites. Because of the different number and timing of visits to low and high risk sites, comparison must be made with caution and is here limited to the first visit to high risk sites. In addition it should be noted that the estimated mortality per km has not been corrected for any bias and power line mortality rates may vary seasonally; all first visits to high risk sites were made in March 2013, whereas visits to low risk sites were spread over the period March to December 2012. The range of bird collisions per km at low risk sites (0 to 44.44 per km) exceeded that for high risk sites (0 to 16.22 per km based on the first visit). The mean estimate of casualties per km at low risk sites was 3.36 (± 0.89; S.E), compared with 6.39 ± 3.57; S.E.at high risk sites (6.39 ± 3.57; S.E; based on the first visit only to high risk sites).

Because collision rates at power lines are likely to be site specific, depending on the range of bird species present, the habitat and topography and characteristics of power lines (e.g. design and orientation in relation to bird flight lines), averaging collision rates over a large number of sites is arguably not meaningful in terms of producing an estimate of collision casualties that can be extrapolated to the length of a national transmission grid. Thus no estimate of bird casualties for the Irish transmission network is presented here.

4.4.3 Bird Species Colliding With Transmission Power Lines in Ireland

The range of bird species found dead during surveys under transmission power lines in the RoI was similar at both high and low risk sites (Figures 9 and 10). In each case only a small number of bird species / species groups were found (excluding unidentified remains, 11 species/ species groups at low risk sites and 10 species/ species groups at high risk sites). The majority of bird remains were of corvids and pigeon species with small numbers of gulls, waders, ducks and passerines.

The literature review (Section 2.4) suggested that herons, swans, geese, raptors (including owls), gamebirds (grouse and pheasants), waders, rails, crakes and some passerines should be considered as susceptible to collisions with power lines. The field surveys carried out in the RoI in 2012 and 2013 did not find any evidence for power line collisions by herons, swans, geese, raptors, or rails. High risk transmission line sites were adjacent to wetland areas (in most cases associated with river SPAs classified for wintering migratory waterfowl) and surveys were carried out during the spring passage period when waterfowl migrate between wintering and breeding areas. Higher numbers of waterfowl (ducks and waders) were found at high risk sites than low risk sites (compare Figures 9 and 10), which might be expected given that high risk sites were selected on the basis of proximity to wetlands. No remains of SPA qualifying species were found during the surveys at high risk sites, although surveys were carried out over a relatively short period of two months during the spring of 2013.

Pigeons and corvids have not been identified as bird species at particular risk of power line collisions (Section 2.4). A recent review of birds and power lines has noted that pigeons were among the species found most frequently under power lines in agricultural areas and wetlands in Western Europe, and also identifies corvids as species with casualties reported from power line collisions but with no resulting significant threats to populations (Prinsen et al., 2011a). Corvids and pigeons are common and widespread bird species in the RoI and this is likely to be why their remains were most frequently found under power lines.

5 FIELD STUDY OF BIRD MORTALITY AT POWER LINES IN IRELAND: COMBINED SURVEYS OF FLIGHT ACTIVITY AND BIRD REMAINS

5.1 INTRODUCTION

Following a review of the field studies undertaken in 2012 and 2013, and described in the previous chapter, a further field study was undertaken in 2014. The aim was to undertake more intensive studies at a small number of sites considered to hold large populations of potentially vulnerable species, to:

(i) obtain further estimates of collision rates and the bird species involved from more intensive searches for bird remains (weekly visits over 2 months), and

(ii) to carry out flight activity surveys focused on species of conservation importance alongside searches for bird remains under power lines.

This provides information on the number of birds of different species crossing transmission power lines and the behaviour of birds in relation to power lines, allowing comparisons between the number of birds of different species crossing power lines in a given area with the number and species of any bird remains found during searches under the power lines.

5.2 METHODS

5.2.1 Study Sites

Three study sites were selected at existing transmission infrastructure. As for high risk sites in the previous study, site selection took account of factors potentially associated with a higher risk of bird collision with power lines, including the presence of water bodies, river valleys, and concentrations of birds. All study sites were in areas where transmission power lines crossed wetlands supporting concentrations of (mainly) wintering and passage birds, and all were in close proximity to Special Protection Areas (SPAs) for wetland birds, classified under the EU Birds Directive (Figure 11). Final site selection was based on topography and potential to view an adequate section of power line for flight activity surveys, as well as the potential to conduct searches for bird remains under at least part of the same section of power line that was included in vantage point (VP) surveys.

The three study sites comprised:

- a section of the Thurles-Shannonbridge 110 kV power line site at Clonony More (County Offaly),

- a section of the Shannonbridge to Killonan 220 kV power line site at Moystown Demesne (County Offaly), and

- a section of the Oldstreet-Woodland 400 kV power line site at Ballymacegan (County Tipperary).

The locations of these sites are shown in Figure 11, detailed site plans are provided in Figures 12, 13 and 14, and photographs in Figures 15,16 and 17.

At Moystown Demesne, the study site included a stretch of single circuit 220 kV non-earthwire power line with metal pylons running north-west from the River Brosna through fields of agricultural grassland. The areas surveyed for flight activity and bird remains are shown in Figure 12; these areas overlapped between the River Brosna and a minor road running north and parallel to the river, the flight activity survey area extended south of the river and the search area for bird remains to the north of the road. This site and Clonony More are close to Clonony Castle in County Offaly. The Clonony More site comprised a section of single circuit non-earthwire 110 kV transmission power line with wooden poles, spanning the River Brosna. Again the power lines run through fields of agricultural grassland either side of the river. At Clonony More, the areas surveyed for bird remains and flight activity overlapped almost completely (Figure 13).

The Ballymacegan study site comprised a section of 400 kV transmission power line crossing the River Shannon at Ballymacegan Island (Figure 14), County Tipperary. Here the power line comprises metal pylons carrying three parallel conducting wires in one horizontal plane, with two earth wires above. In the vicinity of the river, the power line passes over wetlands with small trees, areas that were inundated with flood water at the time that fieldwork began. Further from the river the habitats change to agricultural grassland. At this site, the area of searchable habitat beneath the power lines was limited compared with the area included in flight activity surveys, overlapping only to the west of the river (Figure 14). Sections of the earth wires above the river were marked with aviation balls. Initial site searches had attempted to identify a 400 kV line without markers, but a suitable stretch of power line in relation to wetland areas supporting concentrations of birds could not be found. There were no markers on the lower voltage power lines.

A summary of information for each site is included in Table 4. Details of SPAs within 5km of each site, and qualifying bird species, are included in Table 5.

All field surveys were carried out by suitably qualified ecologists including reconnaissance visits on 25 and 26 February, to finalise study sites and field methods.

Table 4: Characteristics of study sites

Site	1. Moystown Demesne	2. Clonony More	3. Ballymacegan
Line and Voltage	Shannonbridge-Killonan 220 kV	Shannonbridge-Thurles 110 kV	Oldstreet-Woodland 400 kV
Type of pole / pylon	Metal	Wooden	Metal
No. of conducting wires	3	3	3
Earth wire (yes/no)	No	No	Yes
Arrangement of wires	Three parallel conducting wires	Three parallel conducting wires	Three parallel conducting wires and two earth wires above
Height of pylon/ pole (Dimensions *from 2012/2013 study or **EirGrid 2012)	18-26m*	14-18m*	26-54m**
Presence of markers (yes/no)	No	No	Yes Spheres attached to earth wires in central sections above river corridor (between pylons 2-4, Figure 14) within the area surveyed for flight activity. The area searched for bird remains had no markers except for a very short section adjacent to the river.
Length of power line surveyed for flight activity (m)	649m	893m	1616m
No. of poles / pylons within area surveyed for flight activity	3	5	5
Spacing between pylons / poles	363m	153m – 219m	374m – 422m
Length of power line surveyed for bird remains (m)	801m (735m during first two visits before flooding receded)	733m	632m

Figure 11: Location of study sites 2014 and nearby SPAs

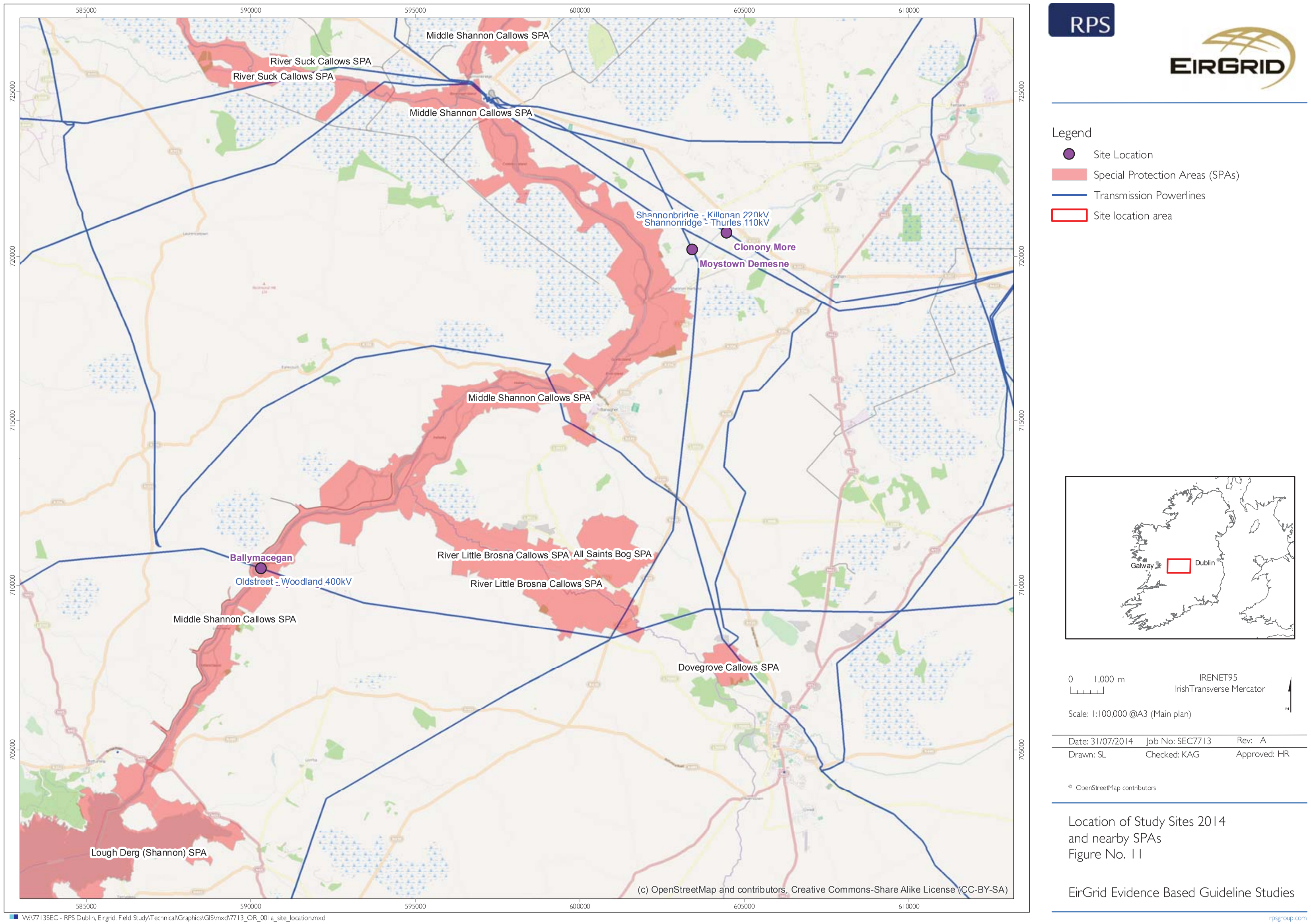


Figure 12: Study site plan: Moystown Demesne

Figure 13: Study Site Plan: Clonony More

Figure 14: Study Site Plan: Ballymacegan

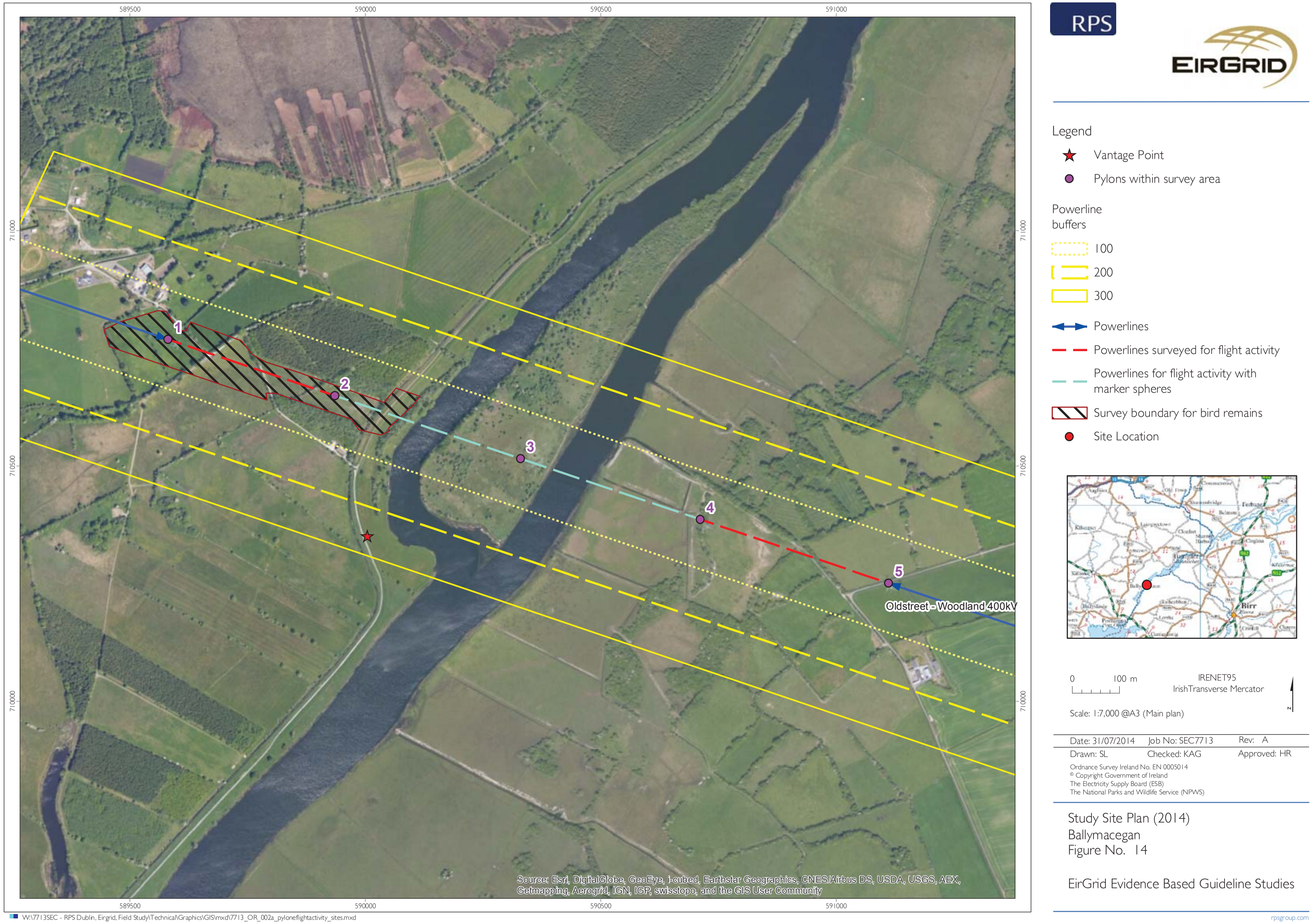


Table 5: SPAs within 5km of transmission power line study sites

Site	SPA (site code)	Proximity to SPA	Qualifying Bird Species[1]	Season[2]
1. Moystown Demesne	Middle Shannon Callows (004096)	Survey area 0.9km from SPA boundary	Whooper swan Wigeon Corncrake Golden plover Lapwing Black-tailed godwit Black-headed gull	W W B W W W,B W
2. Clonony More	Middle Shannon Callows (004096)	Survey area 2km from SPA boundary	As above	
3. Ballymacegan	Middle Shannon Callows (004096)	Survey area within SPA boundary	As above	
	River Little Brosna Callows	Survey area 5km from SPA boundary	Whooper swan Wigeon Teal Pintail Shoveler Golden plover Lapwing Black-tailed godwit Black-headed gull Greenland White-fronted goose	W W W W W W W W W W

1. Based on features of interest listed on the website of the National Parks and Wildlife Service, Ireland http://www.npws.ie/protectedsites/specialprotectionareasspa/. In addition to the qualifying features, the SPA synopses, included on the website, indicate that sites support assemblages of wetland birds throughout the year.
2. W = wintering, B= breeding.

Figure 15: Study site at Moystown Demesne (Shannonbridge-Killonan 220kV line)

Figure 16: Study site at Clonony More (Shannonbridge-Thurles 110kV line)

Figure 17a: Study site at Ballymacegan (Oldsteet-Woodland 400kV line)

Figure 17b: Study site at Ballymacegan (Oldsteet-Woodland 400kV line)

5.2.2 FLIGHT ACTIVITY SURVEYS

5.2.2.1 Aim

The flight activity surveys aimed to systematically record the flight behaviour of birds crossing transmission power lines, including the species and number of birds, approach behaviour and height, crossing behaviour, location and height, and flight behaviour after crossing the power line. Flight activity surveys provided information on the number of birds of different species crossing power lines at the same sites where searches for bird remains were undertaken. Recording the behaviour of birds crossing power lines was also aimed at providing further background in terms of the species and circumstances in which collisions might occur.

5.2.2.2 Methods

There are no standard methods and few published studies of bird flight activity in relation to power lines. Methods were devised with reference to previous studies (in particular Saraveno *et al.*, 1996 and Faanes, 1987).

At each site, flight activity was recorded from a vantage point within 500m of the power line, so that the section of power line in view overlapped with all or part of the area where searches for bird remains were undertaken (Section 5.1.3). VP locations were selected to minimise the potential for observer effects on bird behaviour. At Moystown Demesne and Clonony More, VPs were close to power lines at the end of viewable sections so the observer was not in the flight path of birds before or after crossing, and with a slightly oblique angle to aid judgment of distance (Figures 12 and 13). At Ballymacegan the VP which afforded an optimum view was situated nearly 300m from the power line, potentially within the flight paths of birds. The observer made an effort to be unobtrusive using cryptically coloured clothing and equipment, and reported no detectable reaction from birds within the observation area in terms of changes to flight height, or direction.

Fieldwork was timed to coincide with the end of the overwintering period and the spring passage period for migratory waterfowl, when flight activity is likely to be high. A total of 36 hours of flight activity observation was undertaken at each site between 28 February and 17 April 2014. The dates and times of each visit are provided in Appendix C (Table B.1.1). At each site, the survey effort was spread evenly throughout the day, between dawn and dusk, over the survey period.

Individual flight activity survey (FAS) sessions took place over 3 hour periods, to sample the period from 1 hour before sunrise to 1 hour after sunset and to cover a range of weather conditions. If two consecutive 3 hour sessions were carried out on a given day, the observer took a break of at least half an hour between sessions (as recommended by industry standard guidance on flight activity surveys for wind farms; SNH, 2014).

During each flight activity survey, the observer scanned the area in view and systematically recorded the flight paths and behaviour of bird flocks, where a flock ≥ 1 bird(s). Scanning was done by eye and focal flocks were followed using binoculars. The aim was to record flight behaviour and height for each flock approaching the power line, from the time it crossed an approach or 'start' line 300m perpendicular to the pylon (Figure 18) and entered the sampling zone, until it had crossed the power line and departed the exit line (100m from the pylon, Figure 18), landed within the sampling zone, reversed direction and departed the approach zone, or flown parallel to the line out of sight. The flight data recorded are listed in Table 6 and Figures 18a&b shows a schematic of the power line and recording zone.

When a focal flock passed the approach or start line, a stopwatch with a multiple lap timer was started. Different behaviours were recorded in the order that they occurred with an associated time stamp. If a flock split then an attempt was made to record behaviour and crossing details for all sub-flocks, but if this was not possible then one sub-flock was identified and followed. When a flock crossed a power line, the crossing point was marked (by eye) on a map of the study area and the distance to the nearest pylon recorded.

The observer attempted to record all flocks entering the sampling zone and crossing the power line during each survey period. Where flocks were first seen after crossing the start line (for example because the observer had just finished recording the behaviour of another flock) then this was included in the behaviour summary along with the distance from the power line at which a flock was first seen. In theory crossing rates could be under-estimated if multiple flocks approached the power line at the same time so that the observer could not record all of them. In practice, however, this was rare and it is considered that the only flocks which may have been missed were those flying very low behind vegetation and seen at the last minute after crossing the power lines or the exit line. Any such observations were excluded.

Table 6: Recording codes used during flight activity surveys (after Saraveno *et al.*, 1996 and Faanes, 1987).

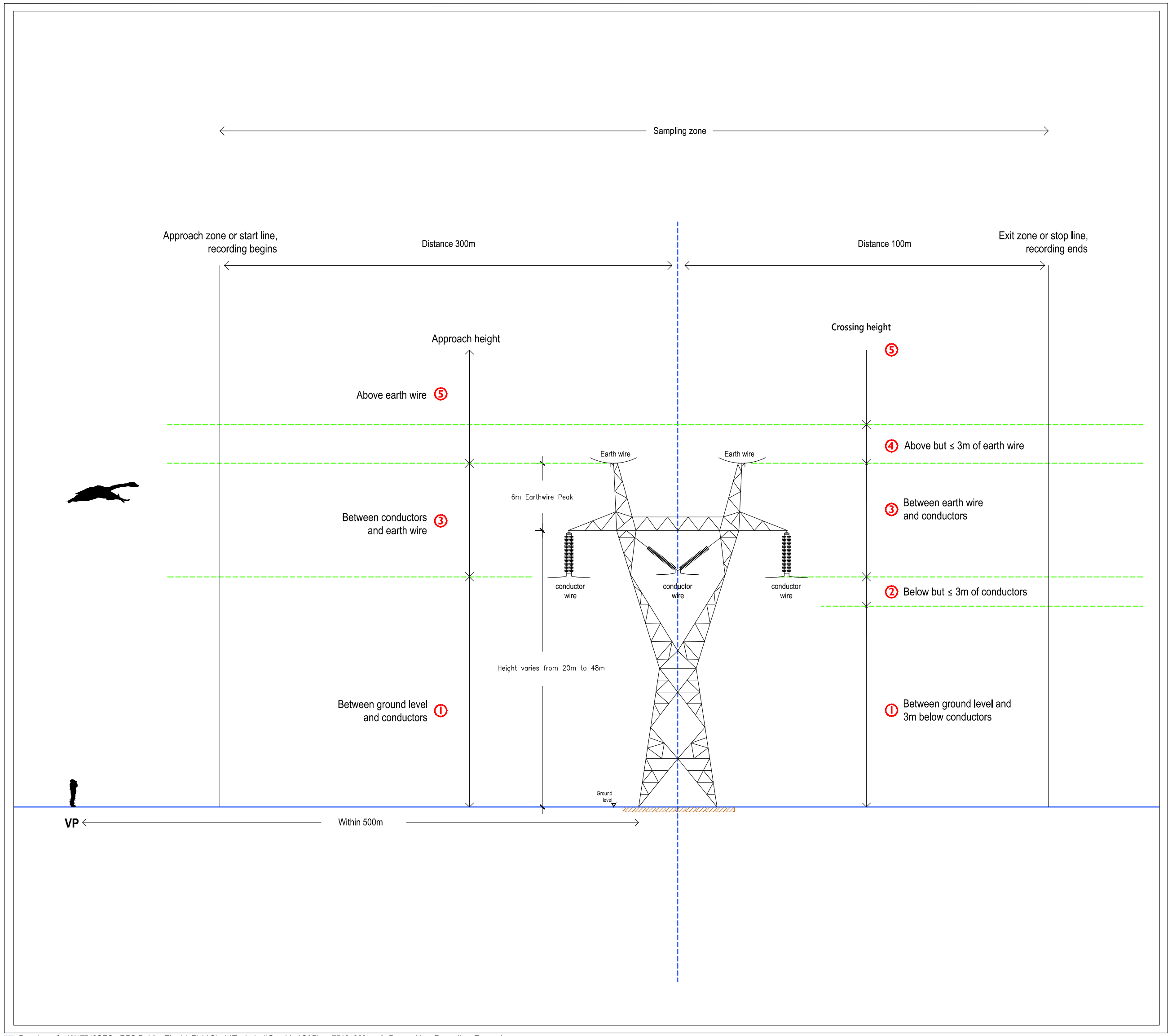
Code	Description
APPROACH / EXIT HEIGHT CODES	
1	Below conductor wires
3	Between conductor and earth wires
5	Above earth wire or highest conducting wire
CROSSING HEIGHT CODES	
1	Between ground and 3m below lowest conductor wires
2	Within 3m but below lowest conductor wires
3	Between conductor and earth wires
4	Within 3m above earth wire or highest conductor wire
5	More than 3m above earth or highest conductor wire
BEHAVIOUR CODES	
1	Crosses power line
2	No change within observation area (constant altitude and unaltered flight)
3	Collision with wires or support structure and bird falls to ground
4	Collision with wires or support structure and bird flies on
5	Near collision, last minute reaction / flare
6	Gradual altitude increase
7	Abrupt altitude increase
8	Gradual altitude decrease

Code	Description
9	Abrupt altitude decrease
10	Lands on earth wire
11	Lands on conducting wire
12	Lands on support structure
13	Lands within sampling area
14	Takes off within sampling area
15	Circles during approach, while crossing or after crossing
16	Fight direction change
17	Turns to fly parallel to power line
18	Aborts – reverses flight during approach and no subsequent crossing
19	Flock scatters
20	Flock splits
21	Flock merges
22	First seen in observation area (after crossing start line)
23	Hovering or near stationary
AGE CODES	
1	Adult
2	Juvenile
3	Immature
4	Sub-adult

As flight activity of birds was high at some sites, recording of flight activity was restricted to target species considered to be of conservation concern and at risk of collision with power lines (literature review, Section 2.2; EirGrid 2012), in particular qualifying species of SPAs. Target species were defined as: waterfowl (ducks, geese and swans), waders, raptors, gamebirds, gulls, herons and cormorant. Flight activity of secondary species, including corvids, passerines and pigeons, was not recorded in detail. During flight activity surveys, activity summaries for secondary species (numbers and location within or outside the recording zone) were recorded for secondary species at five minute intervals, unless the observer was involved in recording the flight activity of a target species.

During flight activity surveys, weather was recorded at the start of each hour, or more frequently if there was a notable change. Variables recorded were: wind speed (Beaufort scale), wind direction, cloud cover and height, visibility, precipitation (rain or snow) and presence of frost or snow (Appendix C, Table B.1.3). The dimensions of the power line were also recorded (Table 4).

Figure 18a: Schematic of transmission power line with earth wires and recording zones for flight activity surveys



Drawing ref: W:\7713SEC - RPS Dublin, Eirgrid, Field Study\Technical\Graphics\CAD\sec7713_003 revA_Power_Line_Recording_Zones.dwg

RPS

EIRGRID

Legend

③ Recording zones

Notes:

All dimensions are indicative only.

Dimensions are in metres unless otherwise stated.

Date: 30.07.14	Scale: nts	Rev:
Job No: SEC7713	Drawn: KAG	Checked: HR

Schematic of Transmission Power Line with Earth Wires and Recording Zones for Flight Activity

Figure No. 18a

EirGrid Evidence Based Guideline Studies

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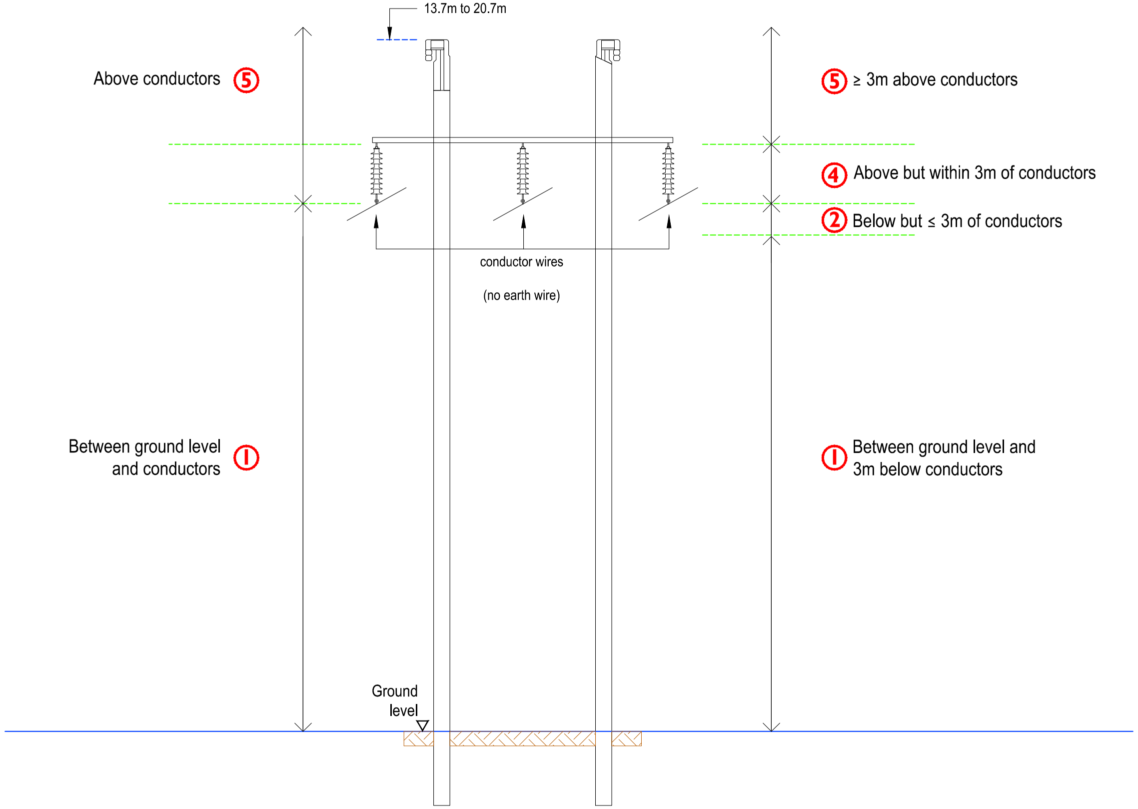
Figure 18b: Recording zones for approach and crossing height for transmission power line without earth wires



RPS EIRGRID

Legend

③ Recording zones

Notes:

All dimensions are indicative only.

Dimensions are in metres unless otherwise stated.

Date: 30.07.14	Scale: nts	Rev:
Job No: SEC7713	Drawn: KAG	Checked: HR

Schematic of Transmission Power Line without Earth Wires and Recording Zones for Approach and Crossing Height

Figure No. 18b

EirGrid Evidence Based Guideline Studies

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5.2.3 Surveys of Bird Remains under Power Lines

5.2.3.1 Aim

The aim was to survey sections of existing transmission power line at various voltages in Ireland for evidence of bird casualties from collision with overhead lines and to generate estimates of collision rates which could be compared with results from the previous field studies in Ireland (Section 4), and elsewhere. (The risk of electrocution of birds on transmission power lines in Ireland is considered to be extremely low (Section 2) and this makes collisions the main likely cause of death at powerlines.)

5.2.3.2 Methods

As for flight activity, there are no standard methods for searches for bird remains under power lines. Methods were devised with reference to the 2012/2013 field studies in Ireland (Chapter 4) and to similar studies and reviews reported in the scientific and 'grey' literature (e.g. APLIC, 2012; Barrientos *et al.,* 2011; Bevanger, 1999).

Search plots were established beneath power transmission lines at each of the three study sites. The areas searched overlapped with the sections of power line identified for flight activity surveys (Figures 12, 13 and 14). The length of power line surveyed at each site was dependent on the habitat and accessible areas at each location. Extensive flooding during the period preceding the surveys limited the searchable areas under power lines at most sites.

Eight weekly search visits for bird remains beneath power transmission lines were carried out at each of the three sites between 4 March and 23 April, coinciding with the timing of flight activity surveys and the late winter and passage period for wintering waterfowl. The dates and times of visits are shown in Appendix C (Table B.1.2).

Survey effort tables in Appendix C include details of overlap between transmission power line sites in the present field study and high risk sites used in field surveys for bird remains carried out in 2013 (Chapter 4). Sites named as Moystown Demesne (1) and Clonony More (2) in the 2014 study overlapped with the Clonony More high risk site from 2013. The latter site, which comprised two lengths of transmission power line of different voltage (Figure 8), was split into two study sites for the 2014 study.

As for the 2012/2013 study, search plots for bird remains were selected only where habitat and ground conditions allowed searches for corpses to be undertaken with a degree of confidence that a similar proportion of those present would be found across sites (Section 4.2.1.3). The presence of waterbodies and wetland habitats were criteria for site selection, but it was not possible to locate search areas directly over waterbodies or wetland habitats with tall vegetation because of the difficulty of searching for bird remains. The availability of suitable search habitat and access permission were constraints on the length of power line that could be surveyed at each site.

Weekly visits were carried out at each study plot to search for bird remains over a 2 month period. The observer searched systematically at each site by walking a series of transects and recording the location and species (if possible) for all bird remains. Searches began at the centreline, directly beneath the power line, and then progressed to parallel transects either side, approximately 10m apart. The sites were predominantly short grazed grassland and minor deviations were made to check small sections containing rushes or taller grass, when a reasonable view into them was not possible from the transect line.

Bird remains were categorised as for the previous study in 2012/2013 (Section 4.2.2):

- intact carcasses;
- scavenged carcasses;
- feather spots (10 or more feathers or two flight feathers); or
- feathers (groups of <10 feathers, not more than one of which is a flight feather).

The location of remains was mapped, a GPS reading taken and the distance from the centre line and the beginning of the study plot recorded. Remains were photographed in situ with a suitable object for indication of scale and then collected and labelled (for identification / verification and to avoid double counting of remains on subsequent visits).

All bird remains were assessed in relation to the possibility that collision, electrocution when perching (rather than collision), or another cause (e.g. shot, predated) was responsible for death. For the purposes of data analysis, it was assumed that all bird remains found during power line searches were collision mortalities unless there was clear evidence to the contrary.

For the previous field studies in Ireland in 2012 and 2013 (Chapter 4), the area within a 45º fall angle from the power line (from the outermost cable on either side) was searched for bird casualties, so that the width of the search area either side of the power lines was the same as the maximum height of the wires (Section 4.2.2). This gave search areas of between 22m and 86m in width, depending on the height of power line.

For surveys in 2014, the aim was to standardise the width of the search area to 50m either side of the power line (a total of 100m), which exceeded the widest area searched for the power lines included in the previous study. In practice however, it was not always possible to search out to 50m either side of power lines because of changes in habitat (e.g. at some sites woodland, which is not readily searchable for bird remains, occurred within 50m), or access limitations. Search areas are shown in Figures 12, 13 and 14.

For the previous study, studies of scavenger removal rates and observer search efficiency were originally proposed to accompany searches for bird remains at transmission power line sites.

However, these were not undertaken because of concerns over public relations implications of asking landowners for permission to lay out bird corpses on private land (Section 4.2.2.2). Thus, proposals for such work were not included in the field methods for studies carried out in 2014. There are examples of published studies of birds and power lines in the literature review which do not include estimations of scavenger removal or observer search efficiency.

5.3 RESULTS

5.3.1 Flight Activity Surveys

5.3.1.1 Collisions and Near Collisions

No collisions of birds with transmission power lines or support structures were observed during flight activity surveys carried out over a period of eight weeks in March and April 2014.

Three near collisions or flares ('last minute reactions) were observed, summarised in Table 7. Two of these events involved the earth wire at Ballymacegan (site 3), and one the conducting wires at Moystown Demesne (Site 1). Adverse weather conditions did not seem to be a factor on any occasion, with wind light to moderate, no rain and good visibility in each instance (Table 7).

Table 7: Near collisions observed during flight activity surveys

Site	Date	Species	Description
1. Moystown Demesne (220kV)	27/03/2014	Little egret	Flock of two birds first seen flying 150m from power line above conductor wires (approach height 5, Figure 18), 07:08, decreased height gradually and split 3m from power line, one flew above and one below the conducting wires. Wind was light, visibility good, and there was no rain (Appendix C, Table B.1.3).
3. Ballymacegan (400kV)	07/03/2014	Mute swan	Flock of two birds first seen flying 200m from power line between ground level and conducting wires (approach height 1, Figure 18) at 07:05, gained height gradually and split 5m from power line, one flew above and one below earth wire. Light wind, no rain and good visibility (Appendix C, Table B.1.3)

Site	Date	Species	Description
3. Ballymacegan (400kV)	28/03/2014	Mallard	Single bird first seen flying 150m from power line between ground level and conducting wires (approach height 1, Figure 18), 15:10, gained height gradually, reacted 10m from power line, and crossed above but within 3m of the earth wire. Moderate wind, no rain, good visibility (Table B.1.3)

5.3.1.2 Target Species and Number of Crossings

The numbers of target bird species recorded crossing power lines during flight activity surveys at each site are listed in Table 8.

A summary of the total crossings recorded for all target species combined, and the total crossings of all bird species per km per hour at each site, is given in Table 9. Crossings per km per hour were calculated separately for each date at each site, from the total number of flocks or birds recorded crossing during observation session(s), divided by the length of power line surveyed and the number of hours observation. Overall mean crossing rates for target species at each of the three sites (i.e. means of the estimated crossing rate from each separate survey day; where two, three hour observation periods were carried out on the same day they were only separated by a period of half an hour so the results were combined) were as follows: Moystown Demesne 2.2 (± 0.6; S.E.) flocks per km per hour and 19.7 (±10.9; S.E.) birds per km per hour; Clonony More 0.7 (±0.2; S.E.) flocks per km per hour and 5.0 (±2.8; S.E.) birds per km per hour; and Ballymacegan 2.4 (±0.3; S.E.) flocks per km per hour and 7.6 (±2.6; S.E.) birds per km per hour. The variation in bird numbers was higher than that of flocks, due to occasional records of large flocks of waders and gulls.

Table 8: Target bird species observed crossing power lines during flight activity surveys at three study sites in Ireland

Site	Species	Taxonomic Group	No. of crossings	
			Flocks	Birds
1. Moystown Demesne (220kV)	Black-headed gull*	Gulls	19	184
	Common gull	Gulls	1	1
	Lesser black-backed gull	Gulls	3	6
	Cormorant	Cormorant	11	15
	Curlew	Waders	1	1
	Golden plover*	Waders	2	212
	Grey heron	Herons	1	1
	Little egret	Herons	5	6
	Mallard	Waterfowl	7	11
	Totals		50	437
2. Clonony More (110kV)	Cormorant	Cormorant	9	11
	Golden Plover*	Waders	3	110
	Grey heron	Herons	4	4
	Mallard	Waterfowl	7	14
	Sparrowhawk	Raptors	1	1
	Totals		24	140
3. Ballymacegan (400kV)	Black-headed gull*	Gulls	12	177
	Common gull	Gulls	2	2

Site	Species	Taxonomic Group	No. of crossings	
			Flocks	Birds
	Great black-backed gull	Gulls	2	2
	Lesser black-backed gull	Gulls	7	8
	Cormorant	Cormorant	88	103
	Black-tailed godwit*	Waders	1	86
	Common snipe	Waders	1	1
	Golden plover*	Waders	1	30
	Mallard	Waterfowl	15	29
	Mute swan	Waterfowl	11	22
	Merlin	Raptors	2	2
	Peregrine	Raptors	1	1
	Totals		143	463
Grand total			217	1040

* Qualifying species of SPAs within 2km of study sites – see Table 5.

Table 9: Total number of target bird species crossing power lines during flight activity surveys at three study sites in Ireland

Site	Length of power line surveyed (km)	Date	Number of crossings		Survey hours	Crossings per km per hour	
			Flocks	Birds		Flocks	Birds
1. Moystown Demesne (220kV)	0.649	28/02/2014	16	158	3	8.22	81.15
		06/03/2014	5	12	3	2.57	6.16
		11/03/2014	3	5	3	1.54	2.57
		14/03/2014	4	5	3	2.05	2.57
		20/03/2014	1	1	3	0.51	0.51
		24/03/2014	2	212	3	1.03	108.89
		27/03/2014	4	4	3	2.05	2.05
		03/04/2014	5	29	6	1.28	7.45
		04/04/2014	5	5	3	2.57	2.57
		10/04/2014	3	3	3	1.54	1.54
		11/04/2014	2	3	3	1.03	1.54
		Total	50	437	Mean (Standard error)	2.22 (0.60)	19.73 (10.91)
2. Clonony More (110kV)	0.893	28/02/2014	1	2	3	0.37	0.75
		06/03/2014	9[1]	12	6	1.68	2.24

Site	Length of power line surveyed (km)	Date	Number of crossings		Survey hours	Crossings per km per hour	
			Flocks	Birds		Flocks	Birds
		13/03/2014	2	5	3	0.75	1.87
		14/03/2014	6	59	3	2.24	22.02
		27/03/2014	2	57	3	0.75	21.28
		03/04/2014	0	0	3	0.00	0.00
		04/04/2014	1	2	3	0.37	0.75
		10/04/2014	2	2	6	0.37	0.37
		11/04/2014	1	1	3	0.37	0.37
		17/04/2014	0	0	3	0.00	0.00
		Total	24	140	Mean (Standard error)	0.69 (0.23)	4.96 (2.79)
3. Ballymacegan (400kV)	1.616	07/03/2014	23	176	6	2.37	18.15
		13/03/2014	23	45	6	2.37	4.64
		14/03/2014	9	95	3	1.86	19.60
		27/03/2014	5	5	3	1.03	1.03
		28/03/2014	40[2]	90	6	4.13	9.28
		04/04/2014	15	17	3	3.09	3.51

Site	Length of power line surveyed (km)	Date	Number of crossings		Survey hours	Crossings per km per hour	
			Flocks	Birds		Flocks	Birds
		08/04/2014	10	12	3	2.06	2.48
		17/04/2014	18	23	6	1.86	2.37
		Total	143	463	Mean (Standard error)	2.35 (0.33)	7.63 (2.61)

1. Includes one flock which crossed three times (back and forth)
2. Includes two flocks which crossed twice.

5.3.1.3 Crossing height

The crossing heights of target species in relation to power lines are summarised in Table 10. The height bands are shown in Figures 18a&b. Identifying height bands within 3m (below) the conducting wires and within 3m (above) the conducting wire or earth wire provides an indication of the number of birds crossing close to wires.

At all three sites, the majority of flocks and birds of target species crossed above the wires. Few or no target species were recorded passing below the wires at Clonony More (site 2) or Moystown Demesne (site 1), whereas 34% of flocks and 15% of individuals of target species passed beneath the wires at Ballymacegan (site 3), which had the tallest pylons.

Table 10: Flight heights of target bird species crossing power lines during flight activity surveys at three study sites in Ireland

Site	Number (and %) of crossings at different heights*									
	Between ground and 3m below conductor wires (1)		Within 3m but below conductor wires (2)		Between conductor and earth wires (3)**		Within 3m but above earth wire or conductor wires (4)		More than 3m above earth or conductor wire (5)	
	Flocks	Birds	Flocks	Birds	Flocks	Birds	Flocks	Birds	Flocks	Birds
1. Moystown Demesne	3 (3%)	4 (1%)	1 (1%)	1 (<1%)	N/A	N/A	8 (16%)	9 (2%)	37 (76%)	422 (97%)
2. Clonony More	0 (0%)	0 (0%)	1 (4%)	2 (1%)	N/A	N/A	7 (29%)	10 (7%)	16 (67%)	128 (91%)
3. Ballymacegan	46 (33%)	67 (15%)	1 (1%)	2 (<1%)	1 (1%)	1 (<1%)	39 (28%)	237 (52%)	53 (38%)	151 (33%)

* Numbers in brackets correspond to crossing height zones in Figure 18.
** Transmission power lines at sites 1 and 2 did not have earth wires.

5.3.1.4 Flight behaviour of birds approaching power lines

The behaviour of each flock observed approaching power lines was classified into one of nine categories as shown in Table 11. Each category of approach behaviour was given a code (with reference to the behaviour codes used for recording flight activity, listed in Table 6). All flocks that (i) were seen from the point of crossing the start or approach line (300m from the power line, Figures 18a and 18b), and (ii) crossed the power line or aborted (codes 1 or 18, Table 6), were considered. Flocks were excluded if they were first seen after crossing the start line (code 22, Table 6), took off within the sampling area before crossing (code 14), landed before crossing (code 13), or landed on the power line or support structure (codes 10, 11 or 12); thus only flocks which were followed from the start line and did not land within the sampling area were considered. Where a (parent) flock split or merged before crossing (behaviour codes 20 or 21), approach codes were assigned only to the resultant sub-flocks formed after the split or merger, to avoid double counting. Where a flock crossed the power line twice during the same observation session, approach behaviour was recorded for the first crossing only.

Table 11: Approach behaviour codes

Code	Description (with reference to behaviour codes in Table 6)
APPROACH BEHAVIOUR	
2	**No change**: behaviour code 2 only recorded pre-crossing
5	**Flare**: any flight with code 5
6	**Gradual height increase**: code 6, and no 5, 7, 8, 9, 15, 16, 17, 18 recorded pre-crossing
7	**Abrupt height increase**: code 7, and no 5, 9, 15, 16, 17, 18 recorded pre-crossing
8	**Gradual height decrease**: code 8, and no 9, 6, 7, 15, 16, 17, 18 recorded pre-crossing
9	**Abrupt height decrease**: code 9, and no 7, 15, 16, 17, 18 recorded pre-crossing
18	**Abort**: any flight with code 18
24	**Hesitation**: any flight with code 15, 16, 17 recorded pre-crossing, no 18
25	**Undulating flight** = 6 and 8 or 7 and 9, no 15, 16, 17, 18 recorded pre-crossing (note any flights with 7 but no 9 recorded pre-crossing, or vice versa were classified as 7 or 9 respectively)

Approach behaviour of target species observed at each study site is summarised in Table 12. At all three sites the majority of flocks and birds crossed with no change or a gradual height increase. More rarely, flocks and birds increased height abruptly, decreased height gradually or abruptly, or aborted. Hesitation, involving changes in direction or circling while approaching the transmission power line, was recorded at Moystown Demesne and Ballymacegan. It was not always clear, however, whether this actually reflected a response to the power line, as flocks exhibiting this behaviour included mallards involved in courtship chasing flights and flocks of Golden Plover circling above power lines. Indeed, all of the aborted crossings recorded (Table 13) involved Mallard and Golden Plover in the same circumstances, and may not have reflected reactions to the power lines.

None of the flares or near collisions which were recorded (Table 7) involved flocks which were observed from a distance of 300m from the power lines.

Birds which landed on pylons were excluded from the analysis of approach behaviour. Two instances of this were recorded, both involving raptors at Moystown Demesne: a merlin landing on the power line on 11 March 2014 at 16:23 and a peregrine at 17:05 on the same day. At Ballymacegan, a non-target species, raven, was observed nesting on one of the pylons within the area surveyed for flight activity.

Table 12: Summary of approach behaviour at each study site

Approach Behaviour	1. Moystown Demesne		2. Clonony More		3. Ballymacegan	
	Flocks	Birds	Flocks	Birds	Flocks	Birds
No change	7 (23%)	51 (12%)	4 (40%)	103 (93%)	29 (37%)	126 (38%)
Flare	0	0	0	0	0	0
Gradual height increase	13 (42%)	33 (8%)	5 (50%)	6 (5%)	23 (29%)	80 (24%)
Abrupt height increase	2 (7%)	9 (2%)	1 (10%)	2 (2%)	11 (14%)	16 (5%)
Gradual height decrease	1 (3%)	3 (1%)	0	0	2 (3%)	3 (1%)
Abrupt height decrease	0	0	0	0	1 (1%)	1 (<1%)
Abort	1 (3%)	95 (22%)	0	0	3 (4%)	63 (19%)

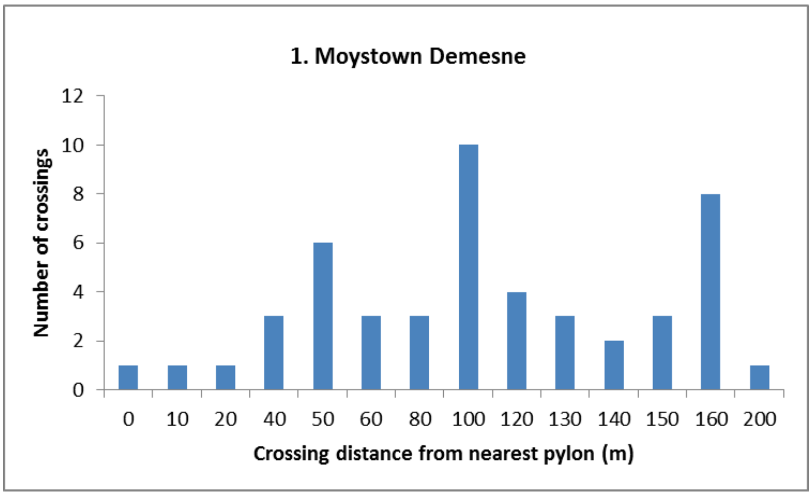
Approach Behaviour	1. Moystown Demesne		2. Clonony More		3. Ballymacegan	
	Flocks	Birds	Flocks	Birds	Flocks	Birds
Hesitation	7 (23%)	236 (55%)	0	0	8 (10%)	41 (12%)
Undulating flight	0	0	0	0	1 (1%)	1 (<1%)
Total	31	427	10	111	78	331
Note: summary includes only flocks which (i) were seen crossing the start or approach line (300m from the power line, Figure 8) and (ii) crossed the power line or aborted (codes 1 or 18, Table 3).						

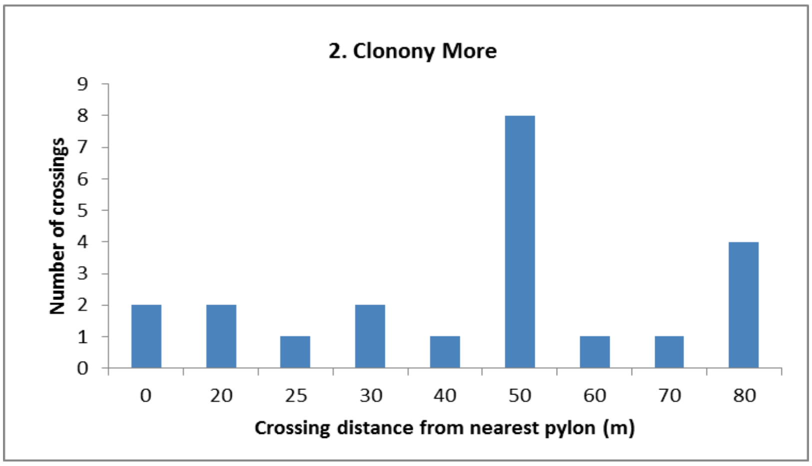
Table 13: Aborted crossings observed during flight activity surveys

Site	Date	Species	Description
1	24/03/2014	Golden plover	Flock of 95 birds circled in wide loops, constantly splitting and re-forming on approach to transmission power line, aborted flight within 20m but well above power line.
2	13/3/2014	Mallard	Flock of 5 birds, 4 males and 1 female, in courtship chase, approached power line more than 3m above height of highest conducting wires, turned back 40m from power line.
3	14/03/2014	Mallard	Flock of 2 birds approaching below height of conducting wires flew parallel to wires, turned back towards wires and then aborted crossing.
3	14/03/14	Golden plover	Flock of 55 birds approaching more than 3m above earth wires turned back 70m from lines.
3	27/03/14	Golden plover	Flock of 6 birds approaching >3m above the height of the earth wires in gradual descent turned back 120m from power line and landed within the sampling area.

5.3.1.5 Crossing distances from pylons

The frequency distribution of distances from pylons for bird crossings is shown in Figure 19. The spacing between pylons at each site was: Moystown Demesne, 363m; Clonony More, 153–219m; Ballymacegan, 374–422m (Table 4). At all three sites very few birds crossed over or close to pylons.





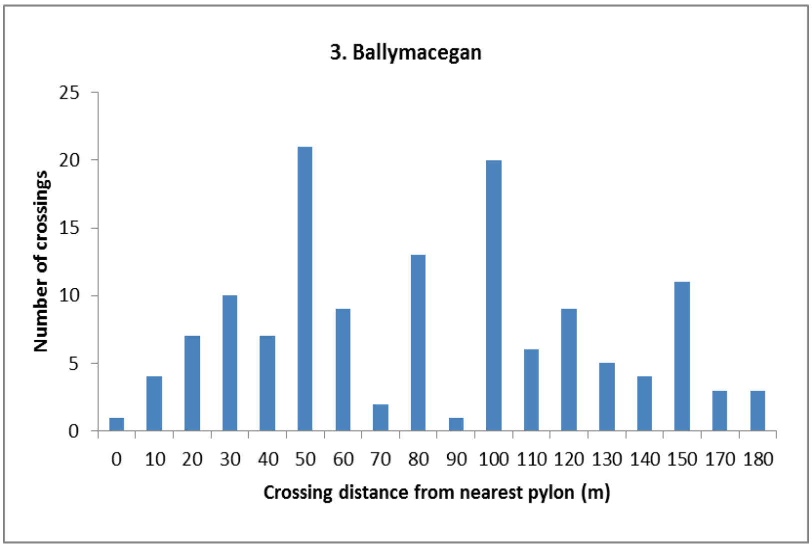


Figure 19: Frequency distribution of the distances from pylons at which birds crossed transmission power lines (distance from nearest pylon estimated by eye). Inter-pylon distances varied at the three sites: 1. Moystown Demesne (220kV), 363m; 2. Clonony More (110kV), 153–219m; 3. Ballymacegan (400kV), 374–422m.

5.3.2 Searches for Bird Remains Under Power Lines

5.3.2.1 Species Detected

Details of the bird remains found beneath transmission power lines during eight weekly searches at each site are listed in Table 14. A total of 16 discrete sets of remains from eight species was recorded. No intact or scavenged carcasses were found; most of the remains were feathers, and there were five feather spots (see bird remains categories in Section 5.2.3.2). The species most frequently recorded were Grey Heron and Woodpigeon, with single records of Redshank, Redwing *Turdus iliacus*, Mallard, Curlew, Jackdaw and Snipe. Ten of the 16 records were bird species associated with wetlands, as might be expected given the proximity of all three sites to rivers and associated wetland areas.

For the purposes of identifying deaths associated with power lines, only feather spots were counted as evidence of a casualty (see Section 4.2.2 above). Assuming all deaths resulted from collisions (given that electrocution is unlikely, and in the absence of clear evidence of other causes of death), the species recorded colliding with power lines at the study sites were: Redwing, Jackdaw, Snipe and Woodpigeon. Of these, only one, Snipe, was a target species as identified for flight activity surveys (Section 5.2.2.2).

5.3.2.2 Collision rates

Assuming that all feather spots found during the site searches were casualties resulting from power line collisions, collision rates for the three study sites are presented in Table 15. Collision rates per km per day were calculated for each visit (except the first one) from the number of casualties found during the visit divided by the length of power line searched and the number of days since the previous visit. The mean of casualty rates from each visit to each site has been used as an overall estimate of collision rate at that site. Given that on most visits at all three sites, no bird casualties were found (so the collision rate was zero birds per km per day), the estimate of the mean is likely to be unreliable. An alternative to the mean would be to use the median value for crossing rates, however this would be zero at all sites.

Over the two month study period the most casualties were found at Moystown Demesne (220kV), with a mean estimate over all visits of 0.08 casualties per km per day, equivalent to 30 per km per year. At Ballymacegan (400kV), the overall mean was 0.03 casualties per km per day equivalent to 9 per km per year. At Clonony More (110kV), a single casualty was found on the first visit only, and over the study period the estimated rate was 0 casualties per day.

Table 14: Bird remains found under power lines

Site	Site name	Date	Species	Certainty*	Category	Distance from centre line (m)
1	Moystown Demesne (220kV)	04/03/2014	Redshank	Probable	Feathers	2
1	Moystown Demesne (220kV)	11/03/2014	Grey Heron	Probable	Feathers	6
1	Moystown Demesne (220kV)	11/03/2014	Grey Heron	Probable	Feathers	13
1	Moystown Demesne (220kV)	11/03/2014	Redwing	Probable	Feather spot	7
1	Moystown Demesne (220kV)	20/03/2014	Grey Heron	Possible	Feathers	50
1	Moystown Demesne (220kV)	20/03/2014	Mallard	Confirmed	Feathers	20
1	Moystown Demesne (220kV)	20/03/2014	Curlew	Confirmed	Feathers	25
1	Moystown Demesne (220kV)	01/04/2014	Jackdaw	Confirmed	Feather spot	0
1	Moystown Demesne (220kV)	11/04/2014	Snipe	Confirmed	Feather spot	0
2	Clonony More (110kV)	04/03/2014	Woodpigeon	Confirmed	Feather spot	14
2	Clonony More (110kV)	11/03/2014	Grey Heron	Probable	Feathers	12
2	Clonony More (110kV)	20/03/2014	Woodpigeon	Probable	Feathers	30
3	Ballymacegan (400kV)	04/03/2014	Woodpigeon	Probable	Feathers	1
3	Ballymacegan (400kV)	20/03/2014	Grey Heron	Probable	Feathers	15

Site	Site name	Date	Species	Certainty*	Category	Distance from centre line (m)
3	Ballymacegan (400kV)	20/03/2014	Grey Heron	Probable	Feathers	15
3	Ballymacegan (400kV)	20/03/2014	Woodpigeon	Confirmed	Feather spot	20

*Confirmed indicates that species identity is certain, probable and possible indicate lower levels of certainty.

Table 15: Bird collision rates at study sites based on searches for bird remains

Site	Search length (km)	Visit no.	Date	Days since last visit	No. of bird casualties	Casualties per km power line	Casualties per km per day	Casualties per km per year
1. Moystown Demesne	0.735	1	4 March 2014	n/a	0	0	n/a	n/a
		2	11 March 2014	7	1	1.36	0.19	71
	0.801	3	20 March 2014	9	0	0	0	0
		4	27 March 2014	7	0	0	0	0
		5	1 April 2014	5	1	1.25	0.25	91
		6	11 April 2014	10	1	1.25	0.12	46
		7	16 April 2014	5	0	0	0	0
		8	23 April 2014	7	0	0	0	0

Site	Search length (km)	Visit no.	Date	Days since last visit	No. of bird casualties	Casualties per km power line	Casualties per km per day	Casualties per km per year
	Mean					0.48	0.08	30
2. Clonony More	0.733	1.	4 March 2014	n/a	1	1.36	n/a	n/a
		2.	11 March 2014	7	0	0	0	0
		3.	20 March 2014	9	0	0	0	0
		4.	27 March 2014	8	0	0	0	0
		5.	1 April 2014	4	0	0	0	0
		6.	8 April 2014	7	0	0	0	0
		7.	16 April 2014	8	0	0	0	0
		8.	23 April 2014	7	0	0	0	0
	Mean					0.17	0	0
3. Ballymacegan	0.632	1.	4 March 2014	n/a	0	0	0	0
		2.	11 March 2014	7	0	0	0.18	64
		3.	20 March 2014	9	1	1.58	0	0
		4.	28 March 2014	8	0	0	0	0

Site	Search length (km)	Visit no.	Date	Days since last visit	No. of bird casualties	Casualties per km power line	Casualties per km per day	Casualties per km per year
		5.	1 April 2014	4	0	0	0	0
		6.	8 April 2014	7	0	0	0	0
		7.	16 April 2014	8	0	0	0	0
		8.	23 April 2014	7	0	0	0	0
	Mean					0.2	0.03	9

As it wasn't possible to consistently survey out to 50m either side of power transmission lines at each site, because of habitat (presence of woodland) or access issues, then the search width either side of the power lines varied within and between sites (see Figures 12, 13 and 14). For valid comparisons of collision rates at each site it would be necessary to identify a common width of search area based on the narrowest search area achieved at any site, and exclude any bird remains found outside this distance, or to control for variation in search area width. However, as it turned out, all of the bird remains which were classed as potential power line casualties (i.e. the feather spots) were within 20m of power lines (Table 14) which is close to the minimum search width achieved consistently at all three sites (see Figures 12, 13 and 14) so no correction has been made.

5.4 DISCUSSION

5.4.1 Flight Activity Surveys

5.4.1.1 Crossing rates

Mean crossing rates for target bird species at three transmission power line study sites in the central RoI were as follows: 220kV line at Moystown Demesne 2.2 (± 0.6; S.E.) flocks per km per hour and 19.7 (±10.9; S.E.) birds per km per hour; 110kv line at Clonony More 0.7 (±0.2; S.E.) flocks per km per hour and 5 (±2.8; S.E.) birds per km per hour; and 400kV line at Ballymacegan 2.4 (±0.3; S.E.) flocks per km per hour and 7.6 (±2.6; S.E.) birds per km per hour. These crossing rates are based on a total of 36 hours flight activity surveys at each site carried out between dawn and dusk between late February and early April 2014. The variation in bird numbers was higher than that of flocks, due to occasional records of large flocks of waders and gulls.

Target bird species were those considered to be of conservation concern and at risk of collision with power lines (waterfowl - ducks, geese and swans, waders, raptors, gamebirds, gulls, herons and cormorant). Crossing rates for each study site would have been higher if flight activity of secondary species (including corvids, passerines and pigeons) had also been recorded, but in practice this would have been logistically difficult for a single field observer to achieve, and could have reduced the amount of information collected in relation to the crossing behaviour of key bird species of concern in relation to power lines.

Fieldwork was scheduled to coincide with the late wintering and spring passage period for migratory waterfowl, and provide an estimate of bird crossing rates during daylight hours over this period. Study sites were located in close proximity to wetlands supporting concentrations of wintering waterfowl, including areas classified as Special Protection Areas (SPAs) for birds under the EU Birds Directive. Wintering waterfowl will typically make daily commuting flights between roosting and feeding periods, and during passage periods there may be a high turnover rate as birds travelling between wintering and breeding areas pass through a number of staging areas. The winter and passage periods are therefore likely to be times of high flight activity and higher risk of collision in relation to power lines.

Part of the transmission power line within the flight activity study area at Ballymacegan included marker spheres on the earth wires which are likely to have made the wires more visible to birds (Table 4, Figure 14). There were no makers on transmission power lines at the other two sites. Initial site searches had attempted to identify a 400 kV line without markers, but a suitable stretch of power line in relation to wetland areas supporting concentrations of birds could not be found.

Few other studies have been found which provide similar data on the rates at which birds cross power lines. At two transmission lines on the South Carolina coast (USA), encounter rates (equivalent to crossing rates) of 38.4 (±0.6; S.E.) birds per km per hour were recorded at a site marked with yellow spheres, and 39.8 (±1.0; S.E.) birds per km per hour at an unmarked site (Saraveno *et al.*, 1996). This was a long term study with data collected over 3 years and respective totals of 3392 and 1,358 observer hours at the two sites; the behaviour of all species of birds except passerines was recorded during encounters with power lines. A study in southwestern Spain included monthly full-day observations of (all) birds flying across two spans of transmission power lines over two consecutive winters (a total of 366 hours of observations between December to April over the two years). Bird crossing rates of 357 crossings per day (rates per hour are not presented) were recorded before ground wires were marked with bird deflectors, which was associated with a significant decrease to 124 crossings per day (Alonso *et al.*, 1994).

Most studies of bird flight activity in relation to power lines involve observations during daylight hours, between dawn and dusk. Birds also fly at night and it has been reported that the risk of collisions with power lines may be highest during darkness (Chapter 2; Prinsen *et al.*, 2011). Recording nocturnal flight activity is difficult because remote sensing equipment is required and the data obtained may not allow identification to species level. A study in the Florida Everglades used a combination of radar and night vision equipment to record birds crossing a 3.7 km section of transmission power line between late February and Early July in one year; it was estimated that an average of 12 flocks crossed the power line per hour of observation (total no. of observation hours not stated), a crossing rate of 3.2 flocks per km per hour (Deng and Frederick, 2001).

5.4.1.2 Collision rates

No collisions between birds and power lines were observed during 108 hours of observation at the three study sites in central Ireland. During this time a total of 217 flocks (where a flock ≥ 1 bird) and 1040 birds of target species were observed crossing transmission power lines. This accords with the findings of other studies which indicate that collisions are rare events. For example, a meta-analysis of studies of birds and power lines (Barrientos *et al.*, 2011) reported 0.21 collisions per 1000 bird crossings at power lines without bird deterrents and 0.05 collisions per 1000 crossings at lines with bird deflectors.

Three near collisions or flares were recorded during the present survey, two of which involved the earth wire at site 3, Ballymacegan (400 kV) and the third involved the conducting wires at Moystown Demesne, a 220 kV power line with no earth wires. Adverse weather conditions did not seem to be a factor on any occasion. The species involved were Mute Swan, Mallard and Little Egret *Egretta garzetta*. Ducks, swans and herons have been identified as bird groups that are vulnerable to collisions with power lines (see Section 2.2.4 above).

It is widely reported that collisions with the earth wires are more frequent (see Section 2.2.3 above), as birds trying to avoid the larger conductor wires fail to see the earth wires (APLIC, 2012: Prinsen *et al.*, 2011; Jenkins *et al.*, 2010; Drewitt and Langston, 2008). Only a few studies have been found that provide quantitative data on this. In North Dakota, 102 (93 %) of 109 birds seen flying into wires during observations at seven power line study sites collided with the earth wire (Faanes, 1987). In South Carolina, 28 (82 %) of 34 collisions observed at two power line study sites involved the earth wire (Savareno *et al.*, 1996). (See also discussion in Section 2.2.3).

5.4.1.3 Crossing height

At all three sites, the majority of flocks and birds of target species crossed above the wires. Few or no target species were recorded passing below the wires at the 110kV line at Clonony More (site 2) or the 220kV line at Moystown Demesne (site 1), whereas 34% of flocks and 15% of individuals of target species passed beneath the lines at the 400kV line at Ballymacegan (site 3). This may be related to the height of the power lines, with the pylons 26-54m in height giving more clearance beneath the conducting wires than at sites 2 and 1 where pylons were respectively 18-26m and 14-18m high (Table 1). Alternatively it may reflect the presence of different bird assemblages of bird species at each study site, and perhaps the tendency of some species to fly lower (the width of the water course crossed by power lines at Ballymacegan was greater than that at the other two sites and some species may tend to fly low over the surface of the water). At Moystown Demesne and Clonony More there were three conducting wires in a horizontal plane and no earth wire (Figures 12 and 13). Transmission power lines at Ballymacegan had three conducting wires in one horizontal plane and two earth wires above (Figure 14). Only 1% of flocks observed crossing the power lines at Ballymacegan crossed between the conductor and earth wires (Table 10).

In south-western Spain, observations of winter flight activity at 380 kV transmission lines with 25-30m pylons found that before installation of bird deflectors, 34% of flocks flew below conductors, 19% between conductors and the ground wire, and 47% above the earth or ground wire. After installation of bird deflectors on the earthwire, the respective proportions were similar at 35%, 14% and 51%. These powerlines consisted of a double circuit arrangement with, conductors arranged in three planes with two overhead earth wires (Alonso *et al.*, 1994).

5.4.1.4 Crossing behaviour

At all three study sites in Ireland the majority of flocks and birds crossed with no change or a gradual height increase (Table 9). More rarely, flocks and birds increased height abruptly, decreased height gradually or abruptly, or aborted. Hesitation, involving changes in direction or circling while approaching the transmission power line, or aborted crossings, often involved Mallards involved in courtship chasing flights and Golden Plover flocks flying well above the height of transmission power lines, and may not have reflected reactions to the power lines (Tables 12 and 13).

In a study of the behaviour of birds crossing power lines at seven sites in North Dakota, most flights (68%) showed no reaction to power lines and a further 25% climbed in altitude until they crossed the ground wire (Faanes, 1987). Five of the seven sites had 230 kV transmission lines with conducting wires in a single plane, one had a 400 kV line with conducting wires in a single plane, and one site had a single-strand 12 kV distribution line.

Observations of the behaviour of birds crossing transmission power lines in coastal South Carolina found that gradual adjustment in height was the most common behaviour and flares least common (Savareno *et al.*, 1996). There was a significant relationship between approach height and behaviour, Flocks approaching at a height equivalent to that between conductor and static wires changed behaviour often, but less so if approaching above the static wires or below the conductor wires.

5.4.2 Bird Collision Rates with Power Lines

Weekly searches over 2 months at three transmission power line sites in Ireland identified as potentially high risk for bird collisions produced estimated collision rates of 0.08 casualties per km per day (30 per km per year) at Moystown Demesne, 0.03 casualties per km per day (9 per km per year) at Ballymacegan, and 0 casualties per km per day at Clonony More. These means are based on very small numbers of bird remains found at each site, with most visits yielding no remains, so should be treated with caution as estimates of the mean at each site are very sensitive to small variations in the numbers found. These rates are also minimal estimates, uncorrected for bias in relation to scavenger removal, observer search efficiency, or crippling (where birds which strike a power line fly out of the search area for bird remains, and may either die as a result of injuries, or recover).

The study suggests that the highest collision rate between birds and power lines was at Moystown Demesne (220kV). However it is also noted that raptors – peregrine and merlin – were observed perching on towers at this site, so it is possible that there is a higher likelihood of bird remains at this site resulting from raptor kills, rather than power line collisions, than at the other sites. This would imply that as well as perching on the towers, raptors plucked their kills on these perches, or on the ground or other perches nearby, so that remains were found in the search areas identified beneath power lines. Such behaviour was not observed in this study, and appears not to have been reported in the literature, although reported observations of raptor kills are in general infrequent. If raptors frequently pluck prey from perches on or near power lines, and some of the bird remains found under power lines are raptor kills rather than collision victims, this could represent a bias towards over-estimating collision mortality; whereas other biases discussed elsewhere in this report (section 2.2.5.1) would tend towards under-estimating collision mortality.

Based on the presence of earth wires as well as conductors, and the highest level of flight activity, it might be predicted that bird collision rates might be highest at Ballymacegan. The presence of markers on the earth wires at this site may have reduced collision rates, although the search area for bird remains only overlapped to a small extent with the marked sections of power line (Figure 14). As the marked sections of power line at this site were those which crossed watercourses, it was not possible to include them in the survey area for bird remains (any birds which collided with power lines and fell into the river would have been washed away).

5.4.3 Comparing Collision Rates from Field Studies in Ireland in 2013 and 2014

Estimated collision rates from field searches under 'high risk' transmission sites in Ireland in 2013 varied from 0 to 0.49 birds per km per day (0 to 179 birds per km per year) (Chapter 4). As was the case with the 2014 estimates, these rates have not been corrected for any potential bias and are considered to be minimum estimates.

High risk sites identified in 2013 comprised single stretches or multiple stretches (in close proximity) of transmission power lines passing over or close to wetlands supporting concentrations of birds. The 2013 fieldwork was carried out over a similar period to that in 2014, over about two months during the late winter/ spring passage period for wintering waterfowl. Fewer repeat visits to each site to search for bird remains were carried out in the 2013 study compared to that in 2014 (and there were no concurrent observations of flight activity).

Direct comparisons between estimated collision rates in 2013 and 2014 can be made for some stretches of power line. Field surveys for bird remains in 2013 produced an estimate of 0.08 bird collisions per km day (equivalent to 28 per km per year) at the Clonony More high risk site, based on three survey visits between 15 March and 20 April (RPS, 2014). This site included two stretches of power line (110 kV and 220 kV) which were re-visited in 2014, with each section of power line considered separately, as: Moystown Demesne (220 kV, site 1 in 2014) and Clonony More (110 kV, site 2). As reported above, collision rates estimated on the basis of eight survey visits between 4 March and 23 April 2014 were 0.08 casualties per km per day (30 per km per year) at Moystown Demesne, and 0 casualties per km per day at Clonony More. For comparison with the 2013 estimate, the combined mean casualty rate at Moystown Demesne and Clonony More in 2014 was 0.04 birds per km per day (15 per km per year; based on data in Table 2). These results from two years of fieldwork appear to suggest broadly similar, low, collision rates of birds, although caution must be applied in interpretation, given the potential sensitivity of the estimates to small differences in the number of bird remains found.

The estimated collision rates for the three study sites where fieldwork was carried out in 2014 do not change the findings, discussed in Chapter 4 (Section 4.4), that collision rates estimated for transmission power line sites in the RoI broadly fall within the range reported in other studies.

The range of bird species represented in remains found under transmission power lines in 2014 was similar to that found in the 2012 and 2013 studies, discussed in Section 4.4.

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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

BIRD REMAINS FOUND DURING FIELD STUDIES IN 2012/2013

Table A1.1 Details of bird Casualties – High Risk Sites

Site code	Site name	Date	Species	Certainty	Category	Distance from centre line (m)	Width of survey area (m)
35	Fermoy	21/03/2013	Corvid	Confirmed	Feather spot	18	40
35	Fermoy	09/04/2013	Gull sp	Probable	Feather spot	9	40
35	Fermoy	06/03/2013	Duck sp	Probable	Feather spot	19	40
36	Fermoy	06/03/2013	Corvid	Confirmed	Feather spot	11	40
36	Fermoy	09/04/2013	Corvid	Confirmed	Feather spot	28	40
36	Fermoy	09/04/2013	Corvid	Confirmed	Feather spot	16	40
36	Fermoy	21/03/2013	Corvid	Confirmed	Feather spot	24	40
36	Fermoy	21/03/2013	Corvid	Confirmed	Feather spot	26	40
36	Fermoy	21/03/2013	Corvid	Probable	Feather spot	6	40
36	Fermoy	06/03/2013	Corvid	Confirmed	Feather spot	27	40
35	Fermoy	21/03/2013	Corvid	Confirmed	Feather spot	18	40
36	Fermoy	06/03/2013	Corvid	Confirmed	Feather spot	14	40
36	Fermoy	09/04/2013	Magpie	Confirmed	Feather spot	32	40
36	Fermoy	09/04/2013	Corvid	Confirmed	Feather spot	25	40
36	Fermoy	09/04/2013	Woodpigeon	Probable	Feather spot	13	40
36	Fermoy	21/03/2013	Corvid	Confirmed	Feather spot	24	40
36	Fermoy	21/03/2013	Corvid	Confirmed	Feather spot	18	40
36	Fermoy	06/03/2013	Woodpigeon	Confirmed	Feather spot	27	40
37	Shannon Bridge	08/03/2013	Woodpigeon	Confirmed	Scavenged	24	26
38	Shannon Bridge	03/04/2013	Feral pigeon	Possible	Feather spot	9	36
41	Shannon Bridge	03/04/2013	Mallard	Confirmed	Scavenged	5	28
41	Shannon Bridge	08/03/2013	Mallard	Confirmed	Scavenged	12	28
42	Shannon Bridge	08/03/2013	Snipe	Confirmed	Scavenged	5	28
42	Shannon Bridge	15/04/2013	Mallard	Confirmed	Feather spot	1	28
42	Shannon Bridge	03/04/2013	Duck sp	Confirmed	Feather spot	2	28
42	Shannon Bridge	08/03/2013	Feral pigeon	Possible	Feather spot	9	28
42	Shannon Bridge	08/03/2013	Unidentified	Unknown	Scavenged	8	28
42	Shannon Bridge	03/04/2013	Snipe	Confirmed	Intact	3	28
43	Kilkenny	27/03/2013	Pheasant	Confirmed	Feather spot	14	28
44	Waterford	11/03/2013	Woodpigeon	Probable	Feather spot	30	86
44	Waterford	11/03/2013	Woodpigeon	Confirmed	Feather spot	19	86
44	Waterford	11/03/2013	Woodpigeon	Confirmed	Feather spot	16	86
45	Clonomy Mor	20/04/2013	Unidentified	Unknown	Scavenged	3	52

Site code	Site name	Date	Species	Certainty	Category	Distance from centre line (m)	Width of survey area (m)
45	Clonomy Mor	05/04/2013	Feral pigeon	Possible	Feather spot	8	52
45	Clonomy Mor	20/04/2013	Blackcap	Confirmed	Intact	7	52
48	Clonomy Mor	20/04/2013	Mallard	Confirmed	Scavenged	4	32

Table A1.2 Details of bird Casualties – Low Risk Sites

Site code	Site name	Date	Species	Certainty	Category	Distance from centre line (m)	Width of survey area (m)
R001	Portlaoise	07/03/2012	Pigeon sp	Poss	Feather spot	0	40
R001	Portlaoise	07/03/2012	Blackbird	Conf	Feather spot	11	40
R001	Portlaoise	07/03/2012	Corvid	Conf	Scavenged	8	40
R002	Reeves Castle	22/03/2012	Woodpigeon	Conf	Feather spot	1	50
R002	Reeves Castle	22/03/2012	Pigeon sp	Conf	Scavenged	3	50
R002	Reeves Castle	22/03/2012	Woodpigeon	Conf	Feather spot	30	50
R002	Reeves Castle	22/03/2012	Woodpigeon	Conf	Feather spot	17	50
R002	Reeves Castle	22/03/2012	Rook	Conf	Feather spot	31	50
R002	Reeves Castle	22/03/2012	Unknown		Feather spot	28	50
R002	Reeves Castle	22/03/2012	Pigeon sp	Conf	Feather spot	26	50
R003	Maynooth	02/04/2012	Pigeon sp	Conf	Feather spot	10	50
R003	Maynooth	02/04/2012	Unknown		Feather spot	23	50
R005	Carbury	03/05/2012	Corvid	Conf	Feather spot	10	22
R005	Carbury	03/05/2012	Lapwing	Poss	Feather spot	19	22
R007	Castleruddery b	04/05/2012	Pigeon sp	Conf	Feather spot	14	64
R009	Tyreallspass	08/05/2012	Corvid	Conf	Scavenged	15	34
R010	Ballyroan	09/05/2012	Pigeon sp	Conf	Feather spot	19	66
R010	Ballyroan	09/05/2012	Rook	Conf	Scavenged	25	66
R011	Ballymooney	09/05/2012	Rook	Conf	Scavenged	5	22
R013	Shelton Abbey	25/06/2012	Corvid	Conf	Feather spot	21	26
R014	Kilbride	25/06/2012	Rook	Conf	Feather spot	0	60
R014	Kilbride	25/06/2012	Unknown		Feather spot	14	60
R015	Roosnaree	26/06/2012	Blackbird	Conf	Feather spot	14	32
R016	Rathkenny	26/06/2012	Corvid	Conf	Feather spot	10	60
R020	Monavallett D	07/07/2012	Pigeon sp	Conf	Feather spot	8	28

Site code	Site name	Date	Species	Certainty	Category	Distance from centre line (m)	Width of survey area (m)
R022	Carrickmines, B	12/07/2012	Feral pigeon	Conf	Feather spot	24	80
R023	Westport	25/07/2012	Corvid	Conf	Feather spot	26	30
R027	Irramore	04/09/2012	Snipe	Conf	Feather spot	0	30
R029	Knocknahoon	06/09/2012	Gull sp	Prob	Feather spot	12	70
R033	Carrigonirtane	30/08/2012	Pigeon sp	Conf	Scavenged	9	50
R033	Carrigonirtane	30/08/2012	Unknown		Scavenged	32	50
R035	Aughnagamun b	23/11/2012	Woodpigeon[1]	Prob	Feather spot	44	24
R035	Aughnagamun b	23/11/2012	Corvid	Conf	Scavenged	11	24
R035	Aughnagamun b	23/11/2012	Tufted duck	Conf	Scavenged	24	24
R035	Aughnagamun b	23/11/2012	Corvid	Conf	Scavenged	26	24
R041	Derreen	12/12/2012	Unknown		Scavenged	1	52
R041	Derreen	12/12/2012	Corvid	Conf	Feather spot	24	52
R042	Carrowgobbadagh	17/12/2012	Corvid	Conf	Feather spot	8	46
R047	Controversy	08/01/2013	Magpie	Conf	Feather spot	18	50
R049	Mohullen a	04/12/2012	Woodpigeon	Conf	Feather spot	1	28
R049	Mohullen a	04/12/2012	Corvid	Conf	Feather spot	12	28
R049	Mohullen a	04/12/2012	Corvid	Conf	Feather spot	7	28
R049	Mohullen a	04/12/2012	Corvid	Conf	Scavenged	6	28
R050	Mohullen b	04/12/2012	Unknown		Scavenged	29	44
R050	Monaraha	30/11/2012	Corvid	Prob	Feather spot	10	28

1. Located outside survey area (defined as an area either side of the power line equivalent to the power line height).

APPENDIX C

SURVEY EFFORT AND WEATHER, 2014 FIELD STUDIES

Table B.1.1: Survey effort for flight activity surveys.

Site	Site name (2014 study)	Site name (2013 study)	Date	Start time	Finish time	Duration (hrs)
1	Moystown Demesne	Clonony More	28 February 2014	08:20	11:20	3
1	Moystown Demesne	Clonony More	6 March 2014	13:05	16:05	3
1	Moystown Demesne	Clonony More	11 March 2014	16:00	19:00	3
1	Moystown Demesne	Clonony More	14 March 2014	06:20	09:20	3
1	Moystown Demesne	Clonony More	20 March 2014	06:05	09:05	3
1	Moystown Demesne	Clonony More	24 March 2014	16:40	19:40	3
1	Moystown Demesne	Clonony More	27 March 2014	05:20	08:20	3
1	Moystown Demesne	Clonony More	3 April 2014	09:40	12:40	3
1	Moystown Demesne	Clonony More	3 April 2014	17:00	20:00	3
1	Moystown Demesne	Clonony More	4 April 2014	14:15	17:15	3
1	Moystown Demesne	Clonony More	10 April 2014	12:40	15:40	3
1	Moystown Demesne	Clonony More	11 April 2014	11:20	14:20	3
					Total	36
2	Clonomy More	Clonony More	28 February 2014	11:35	14:35	3

Site	Site name (2014 study)	Site name (2013 study)	Date	Start time	Finish time	Duration (hrs)
2	Clonony More	Clonony More	6 March 2014	09:45	12:45	3
2	Clonony More	Clonony More	6 March 2014	16:20	19:20	3
2	Clonony More	Clonony More	13 March 2014	06:05	09:05	3
2	Clonony More	Clonony More	14 March 2014	13:45	16:45	3
2	Clonony More	Clonony More	27 March 2014	13:00	16:00	3
2	Clonony More	Clonony More	3 April 2014	13:40	16:40	3
2	Clonony More	Clonony More	4 April 2014	07:00	10:00	3
2	Clonony More	Clonony More	10 April 2014	09:00	12:00	3
2	Clonony More	Clonony More	10 April 2014	16:00	19:00	3
2	Clonony More	Clonony More	11 April 2014	06:45	09:45	3
2	Clonony More	Clonony More	17 April 2014	10:40	13:40	3
					Total	36
3	Ballymacegan	N/A	7 March 2013	06:15	09:15	3
3	Ballymacegan	N/A	7 March 2013	09:45	12:45	3
3	Ballymacegan	N/A	13 March 2013	13:00	16:00	3
3	Ballymacegan	N/A	13 March 2013	16:30	19:30	3

Site	Site name (2014 study)	Site name (2013 study)	Date	Start time	Finish time	Duration (hrs)
3	Ballymacegan	N/A	14 March 2013	10:00	13:00	3
3	Ballymacegan	N/A	27 March 2013	16:40	19:40	3
3	Ballymacegan	N/A	28 March 2013	06:40	09:40	3
3	Ballymacegan	N/A	28 March 2013	12:45	15:45	3
3	Ballymacegan	N/A	4 April 2014	10:40	13:40	3
3	Ballymacegan	N/A	8 April 2014	13:40	16:40	3
3	Ballymacegan	N/A	17 April 2014	07:00	10:00	3
3	Ballymacegan	N/A	17 April 2014	15:45	18:45	3
					Total	36

Table B.1.2: Survey effort for searches for bird remains under power lines. All surveys were carried out by Alan Lauder.

Site	Site name (2014 study)	Site name (2013 study)	Date	Visit	Start time	Finish time
1	Moystown Demesne	Clonony More	4 March 2014	1	08:40	10:50
1	Moystown Demesne	Clonony More	11 March 2014	2	13:45	15:50
1	Moystown Demesne	Clonony More	20 March 2014	3	09:10	11:15

Site	Site name (2014 study)	Site name (2013 study)	Date	Visit	Start time	Finish time
1	Moystown Demesne	Clonony More	27 March 2014	4	08:30	10:35
1	Moystown Demesne	Clonony More	1 April 2014	5	13:50	16:10
1	Moystown Demesne	Clonony More	11 April 2014	6	10:00	16:30
1	Moystown Demesne	Clonony More	16 April 2014	7	07:30	09:30
1	Moystown Demesne	Clonony More	23 April 2014	8	10:30	12:30
2	Clonomy More	Clonony More	4 March 2014	1	11:00	13:35
2	Clonony More	Clonony More	11 March 2014	2	11:15	13:35
2	Clonony More	Clonony More	20 March 2014	3	11:25	13:45
2	Clonony More	Clonony More	27 March 2014	4	10:45	12:50
2	Clonony More	Clonony More	1 April 2014	5	11:30	13:40
2	Clonony More	Clonony More	8 April 2014	6	07:10	09:25
2	Clonony More	Clonony More	16 April 2014	7	09:45	12:10
2	Clonony More	Clonony More	23 April 2014	8	12:45	14:55
3	Ballymacegan	N/A	4 March 2014	1	15:00	17:40

Site	Site name (2014 study)	Site name (2013 study)	Date	Visit	Start time	Finish time
3	Ballymacegan	N/A	11 March 2014	2	08:30	11:00
3	Ballymacegan	N/A	20 March 2014	3	14:20	17:00
3	Ballymacegan	N/A	28 March 2014	4	09:55	12:20
3	Ballymacegan	N/A	1 April 2014	5	08:00	10:40
3	Ballymacegan	N/A	8 April 2014	6	10:05	13:30
3	Ballymacegan	N/A	16 April 2014	7	13:00	15:30
3	Ballymacegan	N/A	23 April 2014	8	07:30	09:50

Table B.1.3: Weather information for flight activity surveys (hourly observations)

Site	Name	Date	Start time	End time	Wind speed[1]	Wind direction	Rain[2]	Cloud cover (eigths)	Visibility[3]	Temperature
1	Moystown Demesne	28/02/2014	08:20	11:20	0		0	1	2	2°C
1	Moystown Demesne	28/02/2014	08:20	11:20	2	NW	0	2	2	4°C
1	Moystown Demesne	28/02/2014	08:20	11:20	2	NW	0	1	2	4°C
1	Moystown Demesne	06/03/2014	13:05	16:05	2	SW	2	8	2	12°C
1	Moystown Demesne	06/03/2014	13:05	16:05	4	SW	2	8	2	12°C
1	Moystown Demesne	06/03/2014	13:05	16:05	3	SW	4	8	2	12°C
1	Moystown Demesne	11/03/2014	16:00	19:00	1	E	0	0	2	13°C
1	Moystown Demesne	11/03/2014	16:00	19:00	1	Variable	0	0	2	10°C
1	Moystown Demesne	11/03/2014	16:00	19:00	0		0	0	2	6°C

Site	Name	Date	Start time	End time	Wind speed[1]	Wind direction	Rain[2]	Cloud cover (eigths)	Visibility[3]	Temperature
1	Moystown Demesne	14/03/2014	06:20	09:20	2	SW	1	8	1	7°C
1	Moystown Demesne	14/03/2014	06:20	09:20	2	SW	1	8	1	7°C
1	Moystown Demesne	14/03/2014	06:20	09:20	2	SW	0	8	1	8°C
1	Moystown Demesne	20/03/2014	06:05	09:05	4	SW	4	8	2	6°C
1	Moystown Demesne	20/03/2014	06:05	09:05	4	SW	4	8	2	6°C
1	Moystown Demesne	20/03/2014	06:05	09:05	3	SW	4	8	1	6°C
1	Moystown Demesne	24/03/2014	16:40	19:40	5	S	2	8	2	6°C
1	Moystown Demesne	24/03/2014	16:40	19:40	6	S	3	8	2	6°C
1	Moystown Demesne	24/03/2014	16:40	19:40	6	S	3	8	2	6°C
1	Moystown Demesne	27/03/2014	05:20	08:20	0		0	3	2	2°C
1	Moystown Demesne	27/03/2014	05:20	08:20	1	E	0	3	2	2°C
1	Moystown Demesne	27/03/2014	05:20	08:20	1	E	0	3	2	3°C
1	Moystown Demesne	03/04/2014	09:40	12:40	4	SSW	0	7	2	12°C
1	Moystown Demesne	03/04/2014	09:40	12:40	4	SSW	2	6	2	14°C
1	Moystown Demesne	03/04/2014	09:40	12:40	3	S	0	4	2	14°C
1	Moystown Demesne	03/04/2014	17:00	20:00	2	S	0	8	2	14°C
1	Moystown Demesne	03/04/2014	17:00	20:00	2	S	0	8	2	12°C
1	Moystown Demesne	03/04/2014	17:00	20:00	2	S	0	8	2	12°C
1	Moystown Demesne	04/04/2014	14:15	17:15	2	S	0	6	2	13°C
1	Moystown Demesne	04/04/2014	14:15	17:15	2	S	0	4	2	13°C
1	Moystown Demesne	04/04/2014	14:15	17:15	3	S	0	3	2	14°C
1	Moystown Demesne	10/04/2014	12:40	15:40	2	SW	1	8	2	12°C
1	Moystown Demesne	10/04/2014	12:40	15:40	2	SW	1	8	2	12°C
1	Moystown Demesne	10/04/2014	12:40	15:40	2	SW	2	8	2	12°C
1	Moystown Demesne	11/04/2014	11:20	14:20	2	W	2	3	2	12°C
1	Moystown Demesne	11/04/2014	11:20	14:20	2	W	2	6	2	12°C
1	Moystown Demesne	11/04/2014	11:20	14:20	2	W	0	8	2	12°C
2	Clonony More	28/02/2014	11:35	14:35	2	NW	0	4	2	4°C
2	Clonony More	28/02/2014	11:35	14:35	2	NW	2	5	2	8°C

Site	Name	Date	Start time	End time	Wind speed[1]	Wind direction	Rain[2]	Cloud cover (eigths)	Visibility[3]	Temperature
2	Clonony More	28/02/2014	11:35	14:35	1	NW	3	5	2	8°C
2	Clonony More	06/03/2014	09:45	12:45	1	SW	0	8	2	12°C
2	Clonony More	06/03/2014	09:45	12:45	1	SW	1	8	2	10°C
2	Clonony More	06/03/2014	09:45	12:45	1	SW	3	8	1	10°C
2	Clonony More	06/03/2014	16:20	19:20	2	SW	3	8	2	12°C
2	Clonony More	06/03/2014	16:20	19:20	2	SW	3	8	2	12°C
2	Clonony More	06/03/2014	16:20	19:20	1	SW	1	8	2	12°C
2	Clonony More	13/03/2014	06:05	09:05	0		0	8	0	2°C
2	Clonony More	13/03/2014	06:05	09:05	0		0	8	0	5°C
2	Clonony More	13/03/2014	06:05	09:05	0		0	8	1	6°C
2	Clonony More	14/03/2014	13:45	16:45	3	W	0	8	2	11°C
2	Clonony More	14/03/2014	13:45	16:45	2	W	0	7	2	13°C
2	Clonony More	14/03/2014	13:45	16:45	3	W	0	8	2	11°C
2	Clonony More	27/03/2014	13:00	16:00	2	E	2	7	2	10°C
2	Clonony More	27/03/2014	13:00	16:00	2	E	0	4	2	12°C
2	Clonony More	27/03/2014	13:00	16:00	3	E	0	6	2	13°C
2	Clonony More	03/04/2014	13:40	16:40	3	S	0	5	2	16°C
2	Clonony More	03/04/2014	13:40	16:40	2	S	0	6	2	17°C
2	Clonony More	03/04/2014	13:40	16:40	2	S	0	8	2	16°C
2	Clonony More	04/04/2014	07:00	10:00	1	S	0	7	2	10°C
2	Clonony More	04/04/2014	07:00	10:00	1	S	0	6	2	12°C
2	Clonony More	04/04/2014	07:00	10:00	2	S	0	6	2	13°C
2	Clonony More	10/04/2014	09:00	12:00	1	SW	0	8	2	12°C
2	Clonony More	10/04/2014	09:00	12:00	1	SW	0	8	2	12°C
2	Clonony More	10/04/2014	09:00	12:00	2	SW	1	8	2	12°C
2	Clonony More	10/04/2014	16:00	19:00	2	W	2	8	2	12°C
2	Clonony More	10/04/2014	16:00	19:00	2	W	0	4	2	10°C
2	Clonony More	10/04/2014	16:00	19:00	3	W	2	4	2	10°C
2	Clonony More	11/04/2014	06:45	09:45	1	W	0	3	2	8°C

Site	Name	Date	Start time	End time	Wind speed[1]	Wind direction	Rain[2]	Cloud cover (eigths)	Visibility[3]	Temperature
2	Clonony More	11/04/2014	06:45	09:45	1	W	0	2	2	9°C
2	Clonony More	11/04/2014	06:45	09:45	2	W	0	2	2	10°C
2	Clonony More	17/04/2014	10:40	13:40	2	NW	0	8	2	12°C
2	Clonony More	17/04/2014	10:40	13:40	2	NW	0	8	2	13°C
2	Clonony More	17/04/2014	10:40	13:40	3	NW	0	8	2	13°C
3	Ballymacegan	07/03/2014	06:15:00	09:15:00	1	W	0	4	2	8°C
3	Ballymacegan	07/03/2014	06:15:00	09:15:00	2	W	2	6	2	5°C
3	Ballymacegan	07/03/2014	06:15:00	09:15:00	2	W	2	4	2	5°C
3	Ballymacegan	07/03/2014	09:45:00	12:45:00	4	W	2	2	2	5°C
3	Ballymacegan	07/03/2014	09:45:00	12:45:00	4	WNW	2	3	2	6°C
3	Ballymacegan	07/03/2014	09:45:00	12:45:00	4	WNW	0	1	2	6°C
3	Ballymacegan	13/03/2014	13:00:00	16:00:00	1	SE	0	8	2	7°C
3	Ballymacegan	13/03/2014	13:00:00	16:00:00	1	NE	0	8	2	6°C
3	Ballymacegan	13/03/2014	13:00:00	16:00:00	1	N	0	8	2	6°C
3	Ballymacegan	13/03/2014	16:30:00	19:30:00	0		0	8	2	5°C
3	Ballymacegan	13/03/2014	16:30:00	19:30:00	1	NW	0	8	2	5°C
3	Ballymacegan	13/03/2014	16:30:00	19:30:00	0		0	8	2	5°C
3	Ballymacegan	14/03/2014	10:00:00	13:00:00	2	SW	0	8	2	7°C
3	Ballymacegan	14/03/2014	10:00:00	13:00:00	2	SW	0	8	2	8°C
3	Ballymacegan	14/03/2014	10:00:00	13:00:00	3	W	0	8	2	10°C
3	Ballymacegan	27/03/2014	16:40:00	19:40:00	3	SE	0	3	2	10°C
3	Ballymacegan	27/03/2014	16:40:00	19:40:00	3	SE	0	2	2	7°C
3	Ballymacegan	27/03/2014	16:40:00	19:40:00	1	E	0	1	2	5°C
3	Ballymacegan	28/03/2014	06:40:00	09:40:00	1	NE	0	7	2	6°C
3	Ballymacegan	28/03/2014	06:40:00	09:40:00	2	NE	0	8	2	8°C
3	Ballymacegan	28/03/2014	06:40:00	09:40:00	3	NE	2	8	2	10°C
3	Ballymacegan	28/03/2014	12:45:00	15:45:00	4	NE	0	4	2	12°C
3	Ballymacegan	28/03/2014	12:45:00	15:45:00	4	NE	0	3	2	13°C
3	Ballymacegan	28/03/2014	12:45:00	15:45:00	4	NE	0	4	2	10°C

Site	Name	Date	Start time	End time	Wind speed[1]	Wind direction	Rain[2]	Cloud cover (eigths)	Visibility[3]	Temperature
3	Ballymacegan	04/04/2014	10:40:00	13:40:00	2	S	0	6	2	12°C
3	Ballymacegan	04/04/2014	10:40:00	13:40:00	1	S	0	6	2	14°C
3	Ballymacegan	04/04/2014	10:40:00	13:40:00	2	S	2	8	2	12°C
3	Ballymacegan	08/04/2014	13:40:00	16:40:00	4	NW	0	6	2	12°C
3	Ballymacegan	08/04/2014	13:40:00	16:40:00	4	NW	0	7	2	12°C
3	Ballymacegan	08/04/2014	13:40:00	16:40:00	4	NW	0	5	2	12°C
3	Ballymacegan	17/04/2014	07:00:00	10:00:00	1	NW	0	8	2	8°C
3	Ballymacegan	17/04/2014	07:00:00	10:00:00	1	NW	0	8	2	8°C
3	Ballymacegan	17/04/2014	07:00:00	10:00:00	2	NW	0	8	2	10°C
3	Ballymacegan	17/04/2014	15:45:00	18:45:00	2	NW	2	7	2	14°C
3	Ballymacegan	17/04/2014	15:45:00	18:45:00	2	W	2	8	2	14°C
3	Ballymacegan	17/04/2014	15:45:00	18:45:00	2	W	2	8	2	12°C

1. Beaufort scale.
2. Rain 0=none, 1=drizzle/mist; 2=light showers, 3=heavy showers, 4=heavy rain.
3. Visibility 0=<1km, 1=1-3km, 2=>3km.