Hen Harrier Conservation and the Wind Energy Sector in Ireland

2022

Preparation of this Report:

The first draft of this report was commissioned by NPWS (now of the Department of Housing, Heritage and Local Government) to inform the development of the Hen Harrier Threat Response Plan (HHTRP) and was prepared by Marc Ruddock. Information on the distribution and characteristics of turbines installed in Ireland up to June 2016 was analysed for the purposes of this report; meanwhile, policy changes and developments up to March 2022 detailed. Due to the time required to finalise the HHTRP, these final additions and updates were made to the report by NPWS and DECC. Members of the HHTRP Interdepartmental Steering Group and Consultative Committee were also consulted on earlier drafts and their comments taken into consideration.

Energy policy context has been rapidly changing since March 2022 onwards, as has biodiversity policy with the development of the EU's Nature Restoration Law and the agreement of the Convention on Biological Diversity's Global Framework for Managing Nature through 2030. Because of the frequency and regularity of developments and their potential for further change in the near future, this report does not describe those that have occurred post-March 2022. However, they will be taken into account in the finalisation of the Hen Harrier Threat Response Plan itself, as will the results of the 2022 National Hen Harrier Survey.

Through the course of the document's preparation, the Departments referenced within it were re-configured a number of times, so their names change throughout. For the purposes of clarity for the reader, these changes are set out below.

- The Department in which the National Parks and Wildlife Service sits changed from the Department of Arts, Heritage, Regional, Rural and Gaeltacht Affairs (DAHRRGA) to the Department of Culture, Heritage and the Gaeltacht (DCHG), and, finally, in 2020, to the Department of Housing, Local Government and Heritage (DHLGH).
- The Department of Communications, Energy and Natural Resources (DCENR) changed to the Department of Communications, Climate Action and Environment (DCCAE) and then, in 2020, to the Department of the Environment, Climate and Communications (DECC).
- The Department of the Environment, Community and Local Government (DECLG) changed to the Department of Housing, Planning, Community and Local Government (DHPCLG), then to the Department of Housing, Planning and Local Government (DHPLG) and then to the Department of Housing, Local Government and Heritage (DHLGH) in 2020, (incorporating NPWS at this time).
- The Department of Agriculture, Food and the Marine remained the same throughout.

Citation:

NPWS, (2022). Hen Harrier Conservation and the Wind Energy Sector in Ireland. Supporting document to the Hen Harrier Threat Response Plan. National Parks and Wildlife Service, Department of Housing, Local Government and Heritage.

An Roinn Tithíochta, Rialtais Áitiúil agus Oidhreachta, 90 Sráid an Rí Thuaidh, Baile Átha Cliath 7, D07 N7CV
Department of Housing, Local Government and Heritage, 90 North King Street, Dublin 7, D07 N7CV

Preface

Directive 2009/147/EC (the Birds Directive) provides a comprehensive regime of protection for all wild birds naturally occurring in the European Union. The Directive instructs Member States to maintain their populations of wild bird species at a level that corresponds in particular to ecological, scientific and cultural requirements, while taking account of economic and recreational requirements. In light of this requirement, Ireland, along with other Member States, shall take the requisite measures to preserve, maintain or re-establish a sufficient diversity and area of habitats for its wild bird species.

The Directive also requires the classification of suitable areas as Special Protection Areas (SPAs) for the protection of certain bird species, including the Hen Harrier. Under Article 6 (2) to (4) of the Habitats Directive, Ireland is obliged to prevent the deterioration of these SPAs (as suitable areas for the species) and only to consent to projects where there is clear scientific evidence that such projects will not lead to an adverse effect on the integrity of the SPA or its qualifying features. The Court of Justice of the European Union, in a number of its findings regarding the interpretation of these Directives, has emphasised the importance of scientific understanding of the impact of proposed interventions, and where there is scientific doubt as to the potential effects on the species or habitats, the precautionary principle must apply.

In growing recognition of the importance of reversing biodiversity decline and its interactions with climate change adaptation and mitigation, international and EU biodiversity policies are being strengthened and Ireland's next National Biodiversity Plan, to be developed in 2022, will reflect these global, European and national contexts.

The Convention on Biological Diversity is currently undertaking negotiations with its Parties to develop the post-2020 global biodiversity framework and move towards achievement of the 2050 Vision of "Living in Harmony with Nature". The EU has also recently adopted its European Green Deal and its constituent element, the EU Biodiversity Strategy to 2030, which is intended to support a green recovery following the Covid-19 pandemic. The Strategy's objective is to put the EU's biodiversity on the path to recovery by 2030 and contains specific actions and commitments, including:

- Establishing a larger EU wide network of protected areas on land and at sea by 2030 (30% on both land and sea, 10% of both being strictly protected)
- Establishing a Nature Restoration Plan, with legally-binding national restoration targets
- Unlocking funding for transformative change and a strengthened governance framework.

The Biodiversity Strategy also includes a requirement that Member States ensure that at least 30% of species and habitats not currently in favourable conservation status achieve that status or show a strong positive trend by 2030, and that none show further signs of deterioration.

At the UN High-Level Summit for Biodiversity in September 2020, An Taoiseach signed up to the Leaders' Pledge for Nature which supports the 30/30 targets and calls for an ambitious and meaningful post-2020 global agreement that will address the biodiversity crisis and help bring about the transformative change needed to halt biodiversity loss on a global level.

The UN Intergovernmental Panel on Climate Change published its sixth assessment report on 28th February 2022. The report highlighted the increasing impacts of greenhouse gas-induced climate change that are being experienced globally and the diminishing window of opportunity to implement measures to mitigate the worst future impacts. The report noted that the impact of unabated climate change upon ecosystems will lead to species migration and extinction. The primary instrument for the mitigation of climate impacts of fossil fuels is a rapid transition from these to renewable energy. For Ireland, the largest available indigenous renewable energy resource is wind energy.

Under the revised 2018 Renewable Energy Directive, the European Union has committed to delivering 32% of gross final consumption of energy from renewable sources by 2030, as part of the EU objective of reducing greenhouse gas emissions. In July 2021, the European Commission launched the Fit for 55 package to give effect to the climate ambition outlined in the European Green Deal and Climate Target Plan, which would increase the EU 2030 greenhouse gas emissions reduction target from 40% to 55% (on a 1990 baseline). The Commission have proposed a range of legislative amendments to give effect to this step-change in ambition, including a revision to the 2018 Renewable Energy Directive to increase the binding renewable energy target from 32% to at least 40% by 2030.

An accelerated transition to renewable electricity will be key to successfully meeting the ambitious renewable energy and greenhouse gas emission reduction targets outlined in the European Green Deal and Climate Action Plan. Onshore wind energy will continue to be one of the leading cost-effective technologies to achieve these targets, as well as displacing emissions in other sectors, including household heating and vehicle transport.

The Climate Action and Low Carbon Development (Amendment) Act 2021 establishes a system of carbon budgeting with a 'carbon budget programme' comprising three five-year economy-wide budgets that set a limit, on an economy-wide basis, for the amount of Greenhouse Gas (GHG) emissions that can be emitted in that period. The carbon budgets will be supplemented by sectoral emissions ceilings, setting the maximum amount of greenhouse gas emissions that are permitted in a given sector of the economy during each five-year carbon budget.

The Climate Action Plan 2021 now commits Ireland to reducing greenhouse gas emissions by 51% over the decade (2021 – 2030), to achieving net-zero emissions by 2050, and to reaching a target of generating up to 80% of electricity from renewable sources by 2030. The indicative renewable electricity capacity targets for Ireland, as set out in the Climate Action Plan 2021, project up to 8 GW of onshore wind by 2030, an increase of up to 4GW on 2019-installed capacity, with the addition of at least 5 GW of offshore wind. Of this renewable capacity at least 500 MW will be delivered through community-based projects, subject to competition as appropriate.

As of March 2022, the invasion of the Ukraine by Russia has triggered an energy crisis with a rapid inflation of energy prices and a risk of energy security being compromised through a restriction in oil and gas supplies. Increasing the utilisation of indigenous renewable energy resources such as wind energy is the best defence that fossil fuel import-dependant countries have to improve their energy security. Furthermore, given the recent rapid growth in demand for power in Ireland, driven primarily by additional large energy users, preserving current capacity whilst adding further renewable electricity generation will be a critical enabler in achieving energy and emissions targets, as well as to protect against security of supply risks.

Up to 700MW of installed onshore wind capacity, or roughly 16% of the current total installed capacity, located within four of the six Hen Harrier Special Protection Areas will have to renew their planning permission or secure planning permission for repowering within the next two decades. The shutdown of this capacity, upon expiry of planning consent, is projected to result in a loss of output of around 1.7TWh/A, an increase in gas requirements for power generation of around 3.4TWh/A, as well as increased carbon dioxide emissions of 628kTCO_2/A. The withdrawal of this capacity from the electricity market is also projected to result in increased prices for consumers and a deterioration in Ireland's security of supply position. A larger number of turbines may in reality be affected, as some wind farms may only partially overlap with an SPA, while the entire wind farm may be denied permission for an extension of duration of planning.

This report specifically examines the interactions between the wind energy sector and Hen Harrier conservation in Ireland. The purpose of this report is to inform the Hen Harrier Threat Response Plan (HHTRP), and its findings will be integrated with those from reports on other key sectors, *i.e.* agriculture and forestry, in order to develop a collaborative cross-sectoral way forward for the conservation of this species.

Disclaimer: Some data utilised in the preparation of this report has been compiled from third-party data sources. Whilst every attempt has been made to verify these data and, although the data have been produced and processed from sources believed to be reliable, no warranty expressed or implied is made regarding accuracy, adequacy, completeness, legality, reliability or usefulness of any information. This disclaimer applies to both isolated and aggregate uses of the information.

Table of Contents

Preparation of this Report: 2

Preface 3

Acknowledgments 7

CHAPTER 1: INTRODUCTION 8

Background 8

The Hen Harrier in Ireland 9

The Wind Energy Sector in Ireland 19

CHAPTER 2: INTERACTIONS BETWEEN WIND ENERGY DEVELOPMENT & THE HEN HARRIER IN IRELAND 38

Introduction 38

Wind energy development -bird interactions 38

Effects of wind energy developments on Hen Harriers 48

Impacts on Hen Harrier Ecology from Wind Energy Development 49

Potential impacts at the nest site 50

Potential impacts at winter roost sites 50

Potential impacts on winter foraging habitat 51

Mitigating the Effects from Wind Energy Developments 51

CHAPTER 3: POTENTIAL POPULATION LEVEL IMPACTS OF WIND ENERGY-RELATED ACTIVITIES ON THE HEN HARRIER IN IRELAND 53

Introduction 53

Potential interactions of wind energy and Irish Hen Harrier breeding populations 53

Potential interactions of wind energy and Irish Hen Harrier SPA breeding populations 67

Potential interactions of wind energy and Irish Hen Harrier breeding populations outside of SPAs 70

Potential interactions of wind energy across the wider countryside 70

Direct disturbance during the breeding season 73

Potential interactions of wind energy developments and Hen Harrier populations outside the breeding season. 75

Other potential interactions of wind energy and Hen Harrier populations 78

CHAPTER 4: SUMMARY OF INTERACTIONS & FUTURE CONSERVATION MANAGEMENT OPTIONS 84

Introduction 84

Summary of interactions 84

Wind Energy and Hen Harrier Conservation 87

Improving the available evidence base for the assessment of future wind energy developments 87

Spatial Planning Policy Development and the Wind Energy Sector 89

Acknowledgments

The National Parks and Wildlife Service of the Department of Housing, Heritage and Local Government would like to thank Marc Ruddock for the first draft of this report and the members of the Hen Harrier Threat Response Plan Inter-Departmental Steering Group and the Consultative Committee for reviewing it and providing necessary content. Thanks are also due to the following NPWS staff for bringing the report to completion: Cliona O'Brien, David Tierney, Sinéad Cummins and Rebecca Jeffrey.

CHAPTER 1: INTRODUCTION

Background

The National Parks and Wildlife Service (NPWS) of the Department of Housing, Local Government and Heritage (DHLGH) is responsible for co-ordinating the conservation of natural habitats and species and the protection of biological diversity in Ireland.

Under Regulation 39 of the European Communities (Birds and Natural Habitats) Regulations 2011-2015, provision is made for the development and implementation of appropriate threat response plans. The purpose of such plans is to cease, avoid, reduce or prevent threats, pressures or hazards that may be having an adverse effect on the conservation status of a species of bird referred to in Article 1 of the Birds Directive, and/or may be causing the deterioration of the habitats of species for which a European Site (or Natura site) has been classified pursuant to the Birds Directive (Directive 2009/ 147/EC).

The Hen Harrier (*Circus cyaneus*) is listed on Annex 1 of the Birds Directive. In 2007, six European Sites (Special Protection Areas (SPAs)) were designated for the conservation of this breeding species. Hen Harriers are also listed for two other SPAs that support important roost sites outside of the breeding season (*i.e.* Lough Corrib SPA and Wexford Harbour and Slobs SPA). A survey of breeding Hen Harrier in 2010 recorded 128 to 172 breeding pairs (Ruddock *et al.*, 2012); this was broadly similar to the totals recorded in the previous survey in 2005 (Barton *et al.*, 2006). However, notable declines were recorded in some of the stronghold SPA sites (Ruddock *et al.*, 2012). The 2015 survey of breeding Hen Harrier (Ruddock *et al*., 2016a) recorded further national declines with 108 to 157 breeding pairs estimated. Further declines were noted within four of the six of the SPAs and overall, the total SPA breeding population of Hen Harriers was shown to have declined by approximately 10% since the 2010 survey and 27% since the 2005 survey.

The results of recent research has raised the possibility that the Hen Harrier may be subject to an ecological trap in Ireland because of its habitat preferences and potential interactions with other land management and land uses. This, coupled with concerns that the extent and rate of change to the Hen Harrier's habitat (due to factors such as continued afforestation, increases in wind energy development and agricultural intensification) were linked to the recently recorded declines, led to the decision to develop a Hen Harrier Threat Response Plan (HHTRP). This document was prepared as part of the HHTRP process and specifically reviews the interactions between the wind energy sector and the conservation of the Hen Harrier population here. Similar reports have been prepared for the forestry and agricultural sectors (NPWS, 2015a and 2015b).

The Hen Harrier in Ireland

A history of the Irish Hen Harrier population (1800s – 1980s)

The Hen Harrier is a widespread, but patchily-distributed, breeding bird across much of northern and central Europe. This European breeding range equates to less than one quarter of its global range (Cramp and Simmons, 1980; Simmons, 2000). The European breeding population is considered to be relatively small (estimated at 32,000 – 59,000 breeding pairs (Birdlife International, 2004)). As the Hen Harrier underwent a large decline between 1970 and 1990, its European conservation status was regarded as 'unfavourable' (BirdLife International, 2004) but it has since been categorised on the European Red List of Birds as 'Least Concern' (BirdLife International, 2015). In Ireland, it is Amber-listed on the Birds of Conservation Concern (Gilbert, Stanbury and Lewis, 2021). It is migratory in the northern parts of its range in north and northeast Europe and Asia, and partially migratory and dispersive in the rest of its breeding range (del Hoyo *et al.*, 1992). Until recent genomic studies, the (Eurasian) Hen Harrier and the (American) Northern Harrier were understood to be the same species.

From the earliest documented records in the 1850s, Hen Harriers were generally distributed throughout Ireland, with breeding strongholds in Kerry, Wicklow and the Tipperary/Waterford border in the south, and Derry and Antrim in the north (Thompson, 1849). The Hen Harrier was also found breeding in Connemara (Shawe-Taylor in Watson, 1977). By 1900, this species was recorded in counties Kerry, Cork, Limerick, Tipperary, Waterford, Wicklow, Dublin, Offaly, Laois, Galway, Mayo, Fermanagh, Donegal, Derry, Antrim and Down. However, it was noted that the population was in decline and no longer present in some historical breeding areas (Ussher and Warren, 1900). At this time, Hen Harriers were considered to have been widely persecuted in Ireland (primarily through the destruction of young and eggs) throughout the latter half of the 19th century (Usher and Warren, 1900; O'Flynn, 1983). Indeed, this species was considered by some to have become extinct as a breeding species in Ireland altogether by the early 1950s (Kennedy *et al.*, 1954; Bannerman and Lodge, 1956). However, small numbers continued to breed in a few areas such as the Slieve Bloom Mountains in Laois, the Tipperary/Waterford border and the Cork/Kerry border (Watson, 1977). There is no accurate historical estimate of Ireland's total breeding population during the early 1950s but it is considered that the Irish population was at historically low levels with regard to numbers and breeding distribution at that time.

It is considered that a recovery in the population started in the 1950s (Andrews, 1964). In 1956, breeding pairs were found in Waterford, south Kilkenny and Cork (O'Flynn, 1983), re-colonising Wicklow soon after, with seven breeding pairs recorded in the county in 1961 (Scott, 1995). By 1964, at least 35 pairs were known to be breeding in six southern counties (O'Flynn, 1983). In the Atlas of Breeding Birds in Britain and Ireland (Sharrock, 1976), an all-Ireland breeding population estimate of 200 – 300 pairs is given, with confirmed or probable breeding records from 17 counties. The distribution was based on fieldwork which was undertaken during the period 1968 – 72. A slightly increased estimate of 250 – 300 pairs is reported for the period 1973-75 (Watson, 1977).

O'Flynn (1983) considered that the recovery of the Hen Harrier breeding population from the 1950s onwards appeared to have been due to an increased availability of secure nest sites and passerine prey species. O'Flynn (1983) cites the government's adoption of a long-term afforestation plan in 1947 of circa 400,000ha to be planted over 40 years as the likely driver of this change, with Hen Harriers using the recently afforested (*i.e.* pre-thicket) areas to both nest in and forage over.

In the latter half of the 1970s, O'Flynn (1983) suspected that the population was no longer increasing. After further investigation, he concluded that the population had declined significantly in some areas (*e.g.* Wicklow from over 20 pairs in 1965 to two or three pairs in 1982), with apparent local extinctions occurring in other areas (*e.g.* Slieve Aughty Mountains, the Ballyhoura Mountains, hills of north Tipperary, hills of south Kilkenny and the Comeragh Mountains in Waterford). O'Flynn (1983) noted that, by the mid-1970s, the earlier-planted conifer forests had grown to maturity, resulting in a direct negative impact on the availability of suitable prey. Coincident changes to open, non-forested habitats in Hen Harrier breeding areas were also occurring at this time. These were partly attributed to Ireland's entry into the European Economic Community (EEC) in 1973 and through subsequent changes in land use initiated by significant investment through the Common Agricultural Policy. O'Flynn (1983) considered that tracts of scrub- and gorse-covered marginal land, which had provided a productive hunting habitat for the Hen Harrier, were cleared and transformed into improved grassland. The combination of the maturation of forest estate and the clearance of marginal land was considered by O'Flynn (1983) to be the main reason for the Hen Harrier breeding population decline of the late 1970s.

Hen harrier in Ireland 1980s to present

O'Donoghue (2004) described the modern landscape of the Irish-breeding Hen Harrier as:

- upland, typically above 100m above sea level (asl) and dominated by pastoral-based livestock farming, with holdings often covered in rushes and bordered by hedgerows;
- active and degraded peatland;
- scrub; and
- commercial forestry plantations of different ages.

Breeding:

Adult birds begin to occupy breeding areas in the uplands in March, with a view to forming pair bonds and to begin nesting. In a two-year study, O'Donoghue (2010) recorded that eggs were laid as early as the 16th of April and as late as the 10th of June, with the median occurring in the first week of May. Incubation per egg is estimated to last 29 – 31 days (del Hoyo *et al.*, 1992). O'Donoghue (2010) noted that the date when chicks fledged ranged from the 18-24th of June to the 6-12th of August, with the fledging peak occurring during the 9-22nd of July.

Nesting Habitat:

The main nesting habitats selected by Hen Harriers in Ireland are:

- pre-thicket stage of first and, particularly, second rotation plantations;
- heather moorland; and
- scrub habitats (see Norriss *et al.*, 2002; Barton *et al.*, 2006; Wilson *et al.*, 2009; O' Donoghue, 2010; Ruddock *et al.*, 2012; Ruddock *et al.*, 2016a).

Harriers will often nest in rides (typically in heather) between plantation blocks or in gaps within mature plantations where there is a suitable dense growth of mature heather or scrub (Ruddock *et al.*, 2012). Hen Harriers have been recorded nesting in mature trees in Northern Ireland (Scott *et al.*, 1991; Ruddock *et al.*, 2008) but incidences of tree-nesting Hen Harriers have not been documented in the Republic of Ireland (O'Donoghue, 2010). Tree-nesting has been less frequently recorded in Northern Ireland in recent years (Scott *et al*., 1991; Ruddock *et al.*, 2008; Hayhow *et al.*, 2013).

O'Donoghue (2010) found that the three main habitat categories used by Hen Harriers for nesting were restocked forest (47%), heather/bog (30%), and scrub (23%). Ruddock *et al.* (2016a) indicated that the majority of Hen Harrier breeding pairs occur in second rotation forest (59%); heather moorland (26%); scrub (8%); first rotation forest (6%) and failed forest (1%).

Hen Harrier nesting preferences in Ireland range between 36m and 385m in altitude (O'Donoghue, 2010), are typically between 100m to 400m (Wilson *et al.*, 2009; Ruddock *et al.* 2012), with the majority recorded between 200m and 400m (63%) and the remaining between 100m to 200m (33%).

Breeding Hen Harriers in Ireland typically avoid agriculturally-improved land for nesting (Wilson *et al.*, 2009), although the species will forage along hedgerows and linear features (Madders, 2000; 2003a). Hen Harrier populations in Ireland are now breeding predominantly in forested landscapes (Barton *et al.*, 2006; O'Donoghue, 2010; Ruddock *et al.*, 2012; Ruddock *et al*., 2016a). These have replaced open heath-dominated upland habitats (O'Flynn, 1983). Conversely, in the UK, the Hen Harrier is recorded more frequently nesting in moorland (Redpath *et al.*, 1998; Sim *et al.*, 2007; Hayhow *et al.*, 2013).

Foraging habitat and diet during the breeding season

The foraging habitat preferences of Hen Harriers in Ireland are generally biased towards moorland, grassland mosaics and pre-thicket forest habitats (see O'Donoghue, 2004; 2010; Barton *et al.*, 2006; Irwin *et al.*, 2012). Post-thicket or mature forest is generally avoided by Hen Harriers for hunting (Madders, 2000; O'Donoghue, 2004). Several studies (see above) have noted that Hen Harriers in Ireland show a preference for nesting in pre-thicket forest habitats. However, observations of foraging behaviour (Madders, 2003; O'Donoghue, 2012) and pellet analysis of breeding pairs, including those in forested landscapes, show that Hen Harriers also use open heath, scrub and farmland habitats for foraging during the breeding season (O'Donoghue, 2010) and in some cases, preferentially use these open, natural habitats (Barton *et al.*, 2006; Ruddock *et al.*, 2012; 2016).

In Ireland, the diet of Hen Harrier is more restricted than that of birds in Britain due to the absence and/or sparse distribution of some small mammal prey species (Ruddock *et al.*, 2008). In the UK, Hen Harrier breeding numbers are typically correlated with the abundance of small mammals (Redpath *et al.*, 2002a; 2002b; Thirgood *et al.*, 2003). However, this relationship does not appear to exist in Ireland, perhaps due to the absence of short-tailed vole (*Microtus agrestis*) (see O'Donoghue, 2010). Preferred prey species in Ireland are Wood Mouse (*Apodemus* *sylvaticus*) and small passerines such as Meadow Pipit (*Anthus pratensis*) and Skylark (*Alauda arvensis*) during the breeding season, whilst Meadow Pipit, Brown Rat (*Rattus norvegicus*) and wintering thrushes predominate in winter (O'Donoghue, 2010). Therefore, comparisons of diet between Ireland and elsewhere need to be undertaken with caution.

There are substantial amounts of Irish-based evidence that show the selection and avoidance of habitats used by foraging Hen Harrier:

- Barton *et al.* (2006) found that foraging adult Hen Harriers did not use habitats in proportion to availability. This study found that heath/bog had the highest selection ratio and so was the preferred habitat for foraging. Pre-thicket forest and scrub were important habitats, with rough grassland having a lower selection ratio. Improved grassland and post-thicket forests had the lowest frequency of use by Hen Harrier, although forested habitats accounted for 53% of the total foraging records.
- Ruddock *et al.* (2012) found that almost 40% of all foraging events observed by surveyors and recorded as part of the 2010 national survey were associated with pre-thicket forests and that 49% of foraging was recorded within open habitats (moorland, grassland and scrub), compared to 43% over forested habitats.
- In a study of Hen Harrier in the Duhallow region of north County Cork and east County Kerry, O'Donoghue (2012) recorded that almost 25% of all foraging flight-lines observed were in pre-thicket forest, with a preference (25% of hunting observations) along linear features (hedgerows) and scrub, as well as moorland (23%) and rough grassland (11%). There was apparent avoidance of mature forest habitats and intensively-managed grasslands.
- Using remote tracking technology, Irwin *et al.* (2012) found that Hen Harriers were more frequently recorded in forested (65%) rather than open habitats (35%), although the study area was biased towards forested habitats. Within forested areas, foraging Hen Harriers showed a preference for second-rotation pre-thicket forest, particularly forest that was 6 - 11 years old, with reduced use of forest 12 – 15 years old. This study also corroborated their preference for foraging along linear features (up to 3-4m wide) and their avoidance of intensively-managed grasslands and forests less than 3 years old and greater than 15 years of age.
- Ruddock *et al.* (2016a) reported that Hen Harriers were more frequently recorded in open habitats (51%) compared to forested habitats (41%). Foraging was most frequently recorded over heather moorland (30.0%) and second-rotation forest (18.7%), rough grassland (12.4%) and thicket stage forest (12.4%).

Population trends since 1990

A second Breeding Bird Atlas was undertaken during the period 1988-91 and an all-Ireland population of 180 breeding pairs was estimated, based on an extrapolation of density estimates across the areas of confirmed or probable breeding (Gibbons *et al.*, 1993). The first national Hen Harrier survey in the Republic of Ireland was conducted during the breeding seasons of 1998 - 2000 and estimated a breeding population of 102 - 129 pairs (Norriss *et al.*, 2002 as described in Barton *et al.*, 2006). A second national survey was undertaken in 2005 and established that its range was within 66 10km squares, as well as a national population estimate of 132 – 153 territorial pairs. This was an increase in numbers of pairs of over 18% from the first national survey; and could be partially explained by increased survey coverage in 2005 (Barton *et al.*, 2006). Combining the results with comparable surveys undertaken in Northern Ireland (Sim *et al.*, 2001; Sim *et al.*, 2007), Barton *et al.* (2006) established all-Ireland estimates of 130-167 and 190–221 territorial pairs in 1998–2000 and 2005 respectively, equivalent to an increase of over 24% in that period.

The third national survey, undertaken in 2010, estimated a breeding population of between 128 to 172 territorial pairs occurring in 69 10km grid squares. A separate survey in Northern Ireland estimated 59 proven and probable territorial pairs (Hayhow *et al.*, 2013), providing an all-Ireland estimate of 158 to 205 pairs (Ruddock *et al*., 2012). These results indicated that the Hen Harrier population appeared to be stable. However, the ability to directly compare the 2005 and 2010 national estimates was complicated by the more than doubling of the surveyor effort in the 2010 survey (Ruddock *et al.*, 2012). The coverage of the 2010 national survey included the 10km squares surveyed in 2005 and therefore, a more accurate comparison was derived by Ruddock *et al.* (2012) by comparing the number of breeding pairs in this subset. The analysis of 113 10km grid squares surveyed in both survey years indicated a population decrease of 6.4% over that five-year period.

A similar sub-sample approach for 84 10km squares surveyed in 1998-2000 and 2010 showed a short-term national population decline of 11 – 14% and 6% reduction in breeding range over this period (see NPWS, 2013a). The 2007 – 2011 Bird Atlas (Balmer *et al.*, 2013) presents the breeding distribution of Hen Harrier within 99 10km squares in the Republic of Ireland but differences in survey methodology and survey effort complicate the interpretation. A large proportion of the records submitted to this Bird Atlas were derived from the 2010 national survey.

The most recent survey data, from 2015 (Ruddock *et al*., 2016a), with 108 – 157 breeding pairs, revealed a further national population decline. This represents a total population decline of 8.7% since 2010. The overall breeding range was observed to have increased, but only for 'possible' breeding pairs, and Hen Harriers were recorded within 83 10km squares (Figure 1), which was a 20.3% increase from 2010 (69 squares).

Supplementary sub-set analyses of data from 139 10km squares that were surveyed in 2010 and 2015 showed a decline of 21.2% in numbers of confirmed breeding pairs (Ruddock *et al*., 2016a). A further sub-set of 110 squares surveyed in 2005, 2010 and 2015 showed a decline of 9.7% in total numbers of territorial pairs from 2005 to 2015 and 16.7% from 2010 to 2015. There was an 8.3% increase recorded in total numbers of territorial pairs between 2005 and 2010 (see also Barton *et al.*, 2006). To establish a long-term trend, Ruddock *et al.*, (2016a) examined 78 10km squares covered in all national surveys (1998-2000, 2005, 2010 and 2015). This shows an overall decline of 33.5% in numbers of territorial pairs between the first national survey (1998-2000) and most recent survey (2015). The proposed 2020 national survey was unavoidably delayed due to the Covid-19 pandemic, and so the 2015 results remain the most recent.

The observed declines in the abundance of breeding birds in the Hen Harrier strongholds, several of which are designated as SPAs, are of particular concern. Six sites have been designated as SPAs for breeding Hen Harriers in Ireland (Figure 2). The SPAs comprise a combined area of some 167,000 hectares (ha) and consist mainly of non-native coniferous plantation forests, open upland peatland habitats, and a spectrum of agricultural grasslands (from unimproved to improved) (NPWS, 2007; Moran and Wilson-Parr, 2015). It is estimated that approximately 52% of the total land area in these six SPAS is afforested. As of June 2016, there were 308 connected wind turbines within or close to (*i.e.* within 500m of) the Hen Harrier SPAs (NPWS, unpublished). The combined breeding Hen Harrier populations within these SPAs during the 2010 national survey (Ruddock *et al.*, 2012) was 77 territories, a decline of 18.1% compared to the 94 territories recorded in the 2005 survey. In 2015, the SPA population accounted for 44-47% of the national population, with between 51 and 69 breeding pairs recorded (Ruddock *et al*., 2016a). This represents a decline of up to 26.6% in numbers of territorial pairs since 2005. In 2015, whilst the overall SPA network population had declined since 2005, the populations of two of the individual SPAs were recorded to have increased whilst the remaining four had declined (see Table 14 in Ruddock *et al*., 2016a).

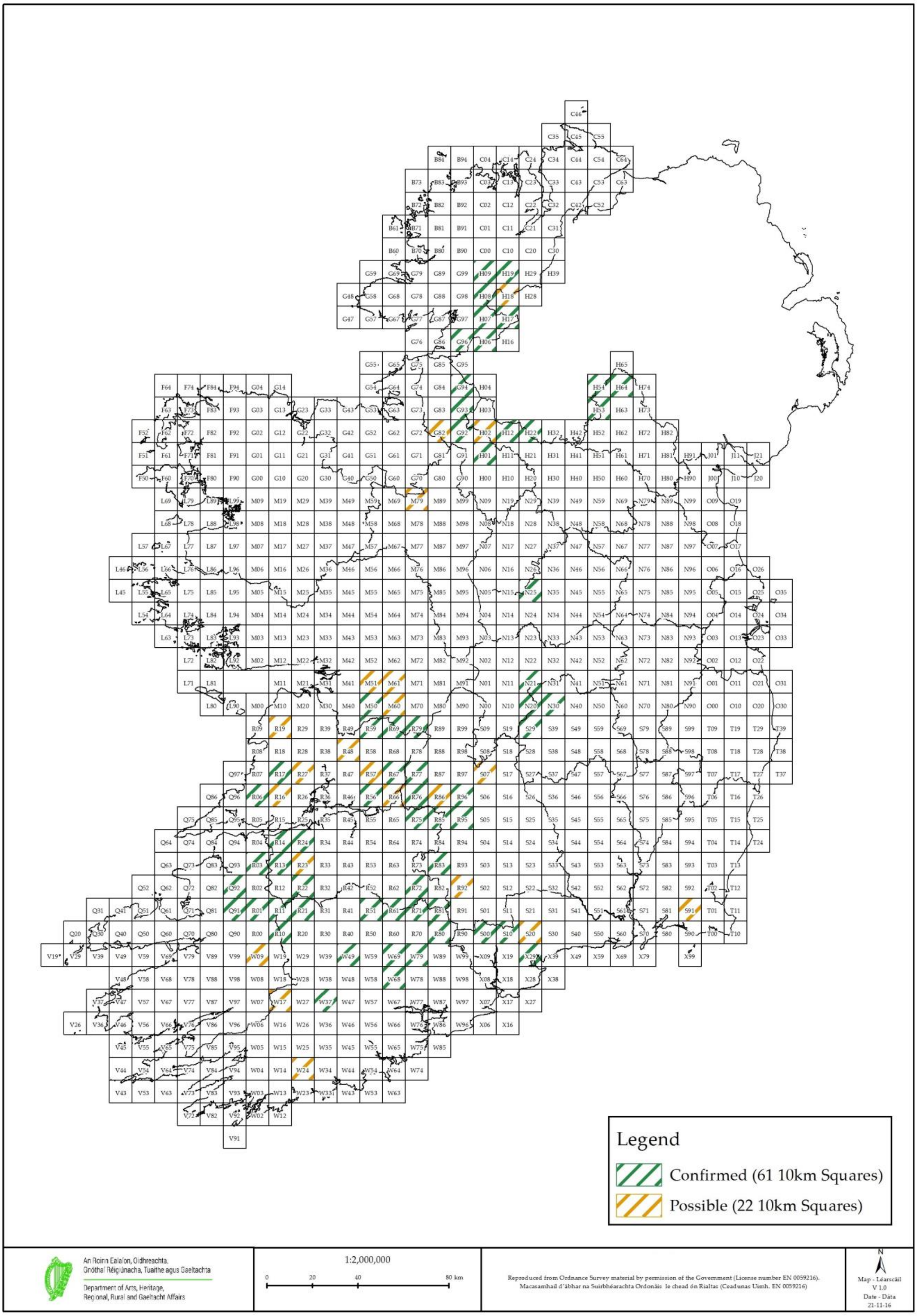

Figure 1. Distribution of Breeding Hen Harrier in 2015

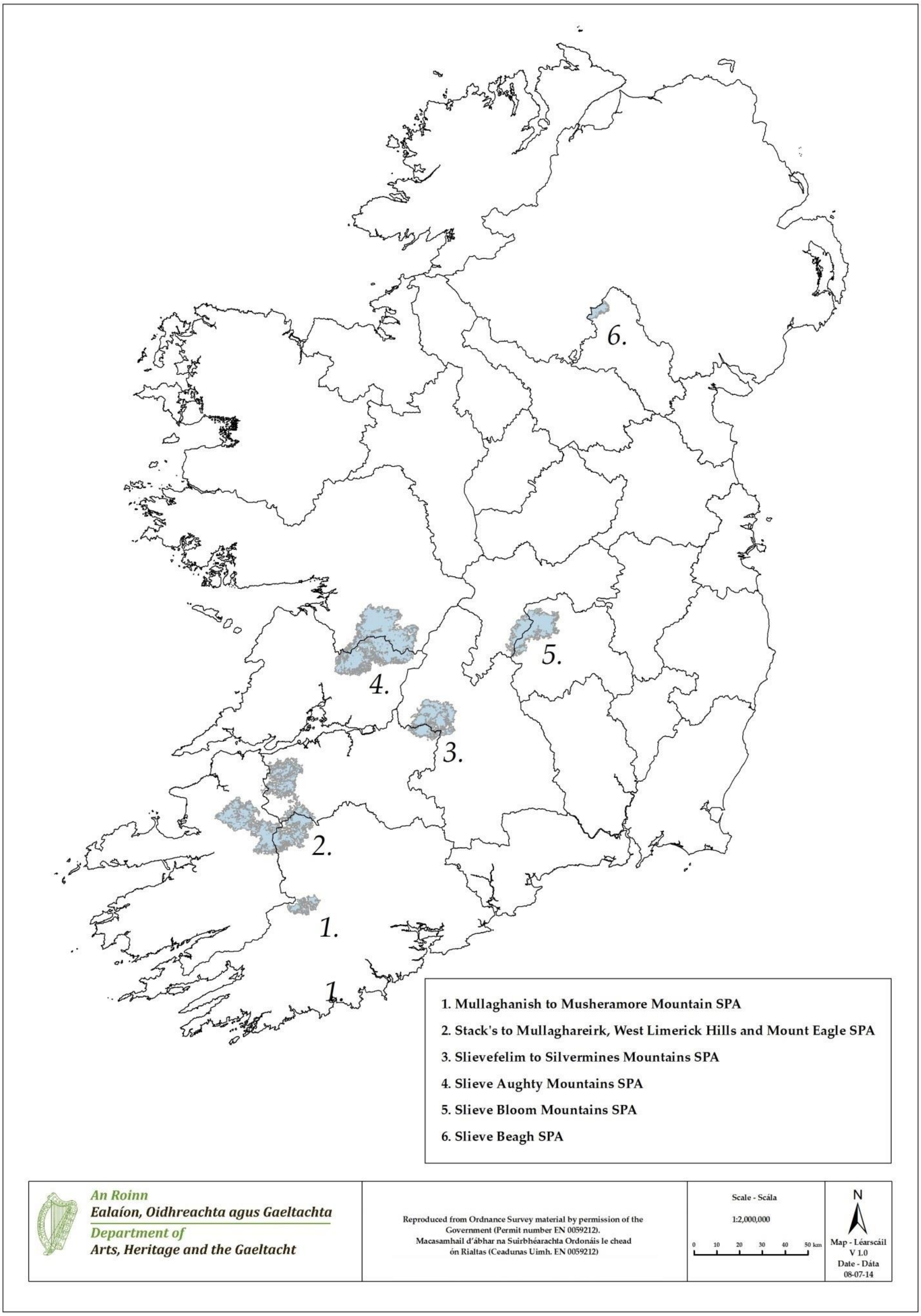

Figure 2. The SPA Network for breeding Hen Harrier.

Outside the Breeding Season (or the Wintering Season)

The winter distribution of Hen Harriers in Ireland differs from that of the breeding season (Figure 3). During the non-breeding season, which can be broadly defined as mid-August to mid-March, Hen Harriers may disperse from the breeding sites, with the majority of marked young birds born in Ireland re-sighted within 150km of their natal site (O'Donoghue, 2010). O'Donoghue (2010) also indicated that Irish Hen Harriers were largely resident, rather than migratory. There are evident population links between Ireland and Britain with records of Scottish-bred birds being re-sighted in Ireland, but the level of cross-over of birds during the breeding and non-breeding periods has yet to be established with certainty (Etheridge and Summers, 2006; O'Donoghue, 2010).

Hen Harrier wintering grounds are reported to typically occur in lowland sites below 100m (Clarke and Watson, 1990; 1997; O'Donoghue, 2010). During the winter, Hen Harrier can gather at communal (frequently used by several birds and other raptors) roost sites at night (Watson and Dickson, 1972). Roost sites may also be solitary (used by individual birds regularly or infrequently) (see Clarke and Watson, 1990). Hen Harriers select roost sites that have suitable cover, low ambient levels of disturbance and are presumably close to suitable foraging areas to roost (O'Donoghue, 2010). In Ireland, the majority of known roosts are located in reedbeds, heather/bog and rank/rough grassland but also in fen, bracken, gorse and saltmarsh (Watson, 1977; O'Donoghue, 2010). Approximately 20% of known roost sites here occur within close proximity to core nesting areas. Only a small number of known roosts are found in forested habitats (O'Donoghue, 2010). The numbers of individual birds occupying each roost site at any one time outside the breeding period are highly variable and patterns of roost site use are poorly understood. In 2014, approximately 96 confirmed winter solitary and communal roosts were known in Ireland, and they were estimated to support between 219 – 313 individuals (B. O'Donoghue, personal communication; see also NPWS, 2015a).

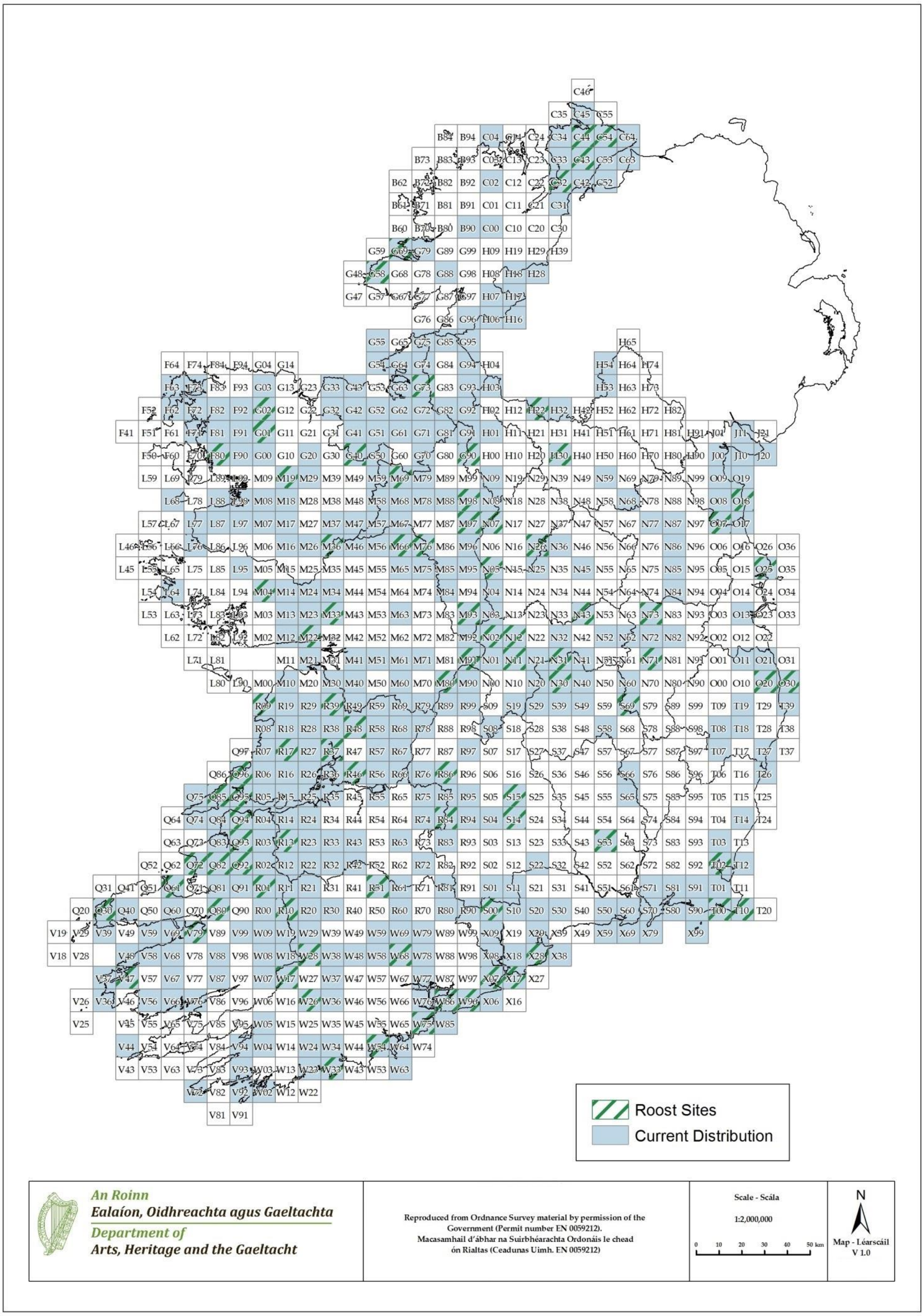

Figure 3. The distribution of wintering Hen Harrier (Distribution data from the 2007-11 Bird Atlas; Roost site locations from unpublished Irish Winter Hen Harrier Survey data).

The Wind Energy Sector in Ireland

The renewable energy sector includes a diverse range of technologies that harness natural energy sources, including solar energy, wind energy, hydro-power (rivers, wave, tidal) energy, geothermal energy and biomass (wood, waste, crops) energy (SEAI, 2016a). Many of these technologies are not considered to be ecologically relevant to Hen Harrier (*i.e.* there are no interactions between them) and thus, are not considered in this review to any degree. This review examines the wind energy sector only (see also Chapters 2 & 3).

Stakeholders in the Wind Energy Sector

Since 2016, DECC (or DCCAE, as it was then) has been responsible for policy and management of wind energy as directed by international and EU obligations. There are a number of commercial, non-commercial and regulatory State bodies under the aegis of DECC that are relevant to the development of wind energy, including the Electricity Supply Board (ESB), EirGrid, Bord na Móna (BNM), the Commission for Regulation of Utilities, and Sustainable Energy Authority of Ireland (SEAI).

SEAI was established as Ireland's national energy authority under the Sustainable Energy Act 2002 and it is central to the delivery of Ireland's renewable energy portfolio, policy and targets. SEAI also has responsibilities with respect to energy efficiency; its "energy efficiency first" philosophy ensures that the reduction of energy demand is considered first in national energy policy, as an alternative to increasing energy supply (*e.g.* SEAI, 2016b).

SEAI has worked in recent years to maintain a database of connected wind turbines and wind energy developments to inform delivery, reporting and analysis of the industry. SEAI also undertakes regular reviews and assessment of energy targets, performance and policy (*e.g.* SEAI, 2011; 2016a) in order to inform government policy, as well as engaging with stakeholders.

SEAI supports also supports relevant research, *e.g.* it has supported BirdWatch Ireland to facilitate work with the International Energy Agency Wind Technology Collaboration Programme (IEA Wind TCP) on WREN (*i.e*. Working Together to Resolve Environmental Effects of Wind Energy). WREN is the leading international forum for supporting the deployment of wind energy technology around the globe, through an improved understanding of environmental issues, efficient monitoring programmes and effective mitigation strategies.

Other Government Departments and agencies may also be considered as stakeholders in the wind energy sector as their plans, programmes, policies and areas of responsibility may be affected by its plans and programmes *etc*. These include, for example, those bodies identified as prescribed bodies in the planning system, such as the National Parks and Wildlife Service (NPWS now sits within the Department of Housing, Local Government and Heritage). NPWS/DHLGH is also an environmental authority, in accordance with the meaning prescribed by the SEA Regulations, and is the lead authority with respect to nature conservation and policy. It is also responsible for the designation of sites for the purposes of nature conservation, including pursuant to the Habitats and Birds Directives, as well as the setting of conservation objectives for same.

DHLGH, through its Planning Section, is also responsible for the development of planning policy and legislation, including the overarching National Planning Framework (NPF) for Ireland's social, economic and cultural development. Local authorities and An Bord Pleanála are also key stakeholders as planning authorities.

The Forest Service of the Department of Agriculture Food and Marine (DAFM) has also become involved in the wind energy sector due to the development of wind energy within afforested sites.

Similarly, academic institutions and non-governmental bodies are involved in undertaking research and providing guidance (*e.g.* Wilson *et al.*, 2015; McGuinness *et al.*, 2015). There are also a significant number of ecologists and environmental scientists engaged in preparing planning applications and the associated ecological assessments for wind energy developments, as well as for relevant plans, programmes and strategies.

Various entities are involved in developing, constructing, operating and maintaining wind turbines or wind energy developments. These include the utility sector, large serial developers, small serial developers, single project developers and asset management companies (International Energy Association, 2015). Examples include State bodies, such as Coillte and Bord na Móna, that develop and operate wind energy developments on state-owned lands, as well as individual landowners or business owners, that may install one turbine in and around their own premises or land-holdings.

There are two representative bodies for the wind energy industry in Ireland:

- Wind Energy Ireland (WEI) (previously the Irish Wind Energy Association or IWEA) has over 150 members and engages laterally with counterparts in the British Wind Energy Association (BWEA; Renewable UK) and the European Wind Energy Association (EWEA). There are also extensive north-south co-operation mechanisms within WEI for consideration of All-Ireland industry issues, as well as an Ireland-UK working group for Northern Ireland, RenewableNI, facilitated by WEI and Renewable UK;
- Meitheal na Gaoithe, the Irish Wind Farmers' Association which is a representative body and lobby group for independent wind energy developers. It has over 70 members.

Policy and legislative context for the development of wind energy developments in Ireland:

The wind energy sector is governed and influenced by a wide range of policy and legislative drivers, including those of the energy sector itself, but also those concerning planning, climate change, biodiversity and the wider environment, heritage as well as other land-use sectors, such as forestry and agriculture. This broad context is described in more detail below.

-Renewable energy context

The primary global framework governing the development of renewable energy began at the United Nations (UN) Framework Convention on Climate Change (1994). Subsequently, amendments to the UNFCC were adopted through the Kyoto Protocol (1997), the Integrated

Energy and Climate Change Package (2007), and more recently, the Paris Agreement (2016). The Paris Agreement sets out a global framework for the avoidance of dangerous climate change, by the limitation of global warming to well-below 2°C, and by the pursuance of efforts to limit warming to 1.5°C. The EU's contribution, adopted for all Member States under the Paris Agreement, is to reduce greenhouse gas emissions by at least 40% by 2030 compared to 1990.

The EU 2030 Climate and Energy Framework, adopted in 2018, incorporates EU legislative measures to achieve three EU-level key targets:

- at least a 40% reduction in greenhouse gas emissions;
- at least a 32% share for renewable energy; and;
- at least a 32.5% improvement in energy efficiency.

The 32% EU-wide renewable energy target is given effect through the recast Renewable Energy Directive (2018/2001/EU) and the Regulation on the Governance of the Energy Union and Climate Action (EU) 2018/1999 (the Governance Regulation). As part of the Governance Regulation, Member States prepared National Energy and Climate Plans (NECPs) for 2021-2030, outlining the measures they will take to meet the 2030 targets for, *inter alia*, renewable energy and energy efficiency. Ireland's first NECP 2021-2030 (DCCAE, 2020) outlined the policies adopted to deliver on a national target of 34% of gross final consumption of energy from renewable sources by 2030, including a 70% renewable share in electricity production. The first NECP does not take into account the increased EU climate ambitions – for a 55% reduction in greenhouse gas emissions over 2021–2030 – that are outlined in the proposed amendment of the 2018 Renewable Energy Directive.

In December 2019, the European Commission issued a communication on the European Green Deal (EGD), which set an ambition to achieve climate neutrality – or net-zero greenhouse gas emissions - by 2050 and, as an intermediate step, a 50-55% reduction in EU-wide GHG emissions by 2030 (on 1990 baseline levels) (European Commission, 2019). In December 2020, the European Council agreed to adopt a 55% target for 2030. On foot of the EGD Communication and Council's agreement, the Commission will bring forward a range of legislative proposals in 2021 to give effect to this step change in ambition, including a revision to 2018 Renewable Energy Directive to increase the binding renewable energy target. Any increase in the renewable energy target will require the additional deployment of renewable electricity as one of the key mechanisms to decarbonise the wider energy sector (*i.e.* heat and cooling and transport) in the electrification of those sectors.

EU legislation also provides the framework for the regulation and design of the EU internal market in electricity, which was most recently updated through the *Clean Energy for all Europeans* package of legislative measures, including the Directive on Common Rules for the Internal Market for Electricity (EU) 2019/944, the Regulation on the Internal Market for Electricity (EU) 2019/943, the Regulation on Risk Preparedness in the Electricity Sector (EU) 2019/941 and Regulation (EU) 2019/942 which establishes an EU Agency for the cooperation of energy regulators.

Domestic legislative and policy framework

Renewable energy, including wind, is a key part of the Irish Government's commitments to a secure, sustainable energy strategy (DCENR, 2012a; 2014a and 2014b; 2016), energy transmission infrastructure (DCENR, 2012b) and low carbon policy (DCENR, 2015). The present policy context is shaped by the 2021 Climate Action Plan (DECC, 2021), which sets out the indicative renewable electricity capacity required to meet the policy of achieving an up to 80% renewable share in electricity by 2030, including an increase in onshore wind capacity from 4.2 GW up to 8GW over the decade 2021 – 2030.

The key Irish legislative instruments governing the renewable electricity sector include the Electricity Regulation Act 1999, which outlines domestic regulatory arrangements for the electricity sector; the Sustainable Energy Act 2002; the Energy Efficiency Directive 2012/27/EU implemented via SI 426/2014 and SI 131/2014; the 2009 Renewable Energy Directive (2009/28/EC), implemented via SI 483/2014 (which will be superseded by the 2018 Renewable Energy Directive from July 2021); and the EU Services Directive 2006/32/EU (via SI 542/2009).

Future policy development

Further expansion of renewable electricity will be required to meet Ireland's contribution to the 2030 renewable energy target, particularly in the context of the 2020 Programme for Government commitment to a 7% per annum reduction in greenhouse gases for the period 2021-2030 and the revised EGD greenhouse gas target. The deployment of renewable electricity technologies will be driven by technology costs and competitive auctions under the Renewable Electricity Support Scheme (RESS) as well as major private sector funding through Corporate Power Purchase Agreements.

To date, onshore wind has been the largest driver of growth in renewable energy electricity, primarily due to its cost-effectiveness when compared to other renewable technologies. In order to support the target to generate 40% electricity from renewable sources by 2020, DECC facilitates financial incentivisation of renewable energy generation via the Renewable Energy Feed in Tariff (REFIT). This scheme, funded by the Public Service Obligation (PSO) and paid via electricity consumers, subsidises renewable electricity generators based on electricity output (per kilowatt hour). DECC is currently operating the new Renewable Electricity Support Scheme (RESS). It is aimed at ensuring Ireland meets its 2030 renewable electricity target, providing support to renewable electricity projects and aiming to increase technology diversity and energy sustainability, and help decarbonise the energy sector.

SEAI also provides grants and subsidies to encourage renewable energy research development, demonstration, and energy efficiency.

- Biodiversity and Nature policy context

The renewable energy industry, its policies, planning and implementation, are also subject to, and require compliance with, a number of EU Directives. These include the Strategic Environmental Assessment (SEA) Directive (2001/42/EC); Environmental Impact Assessment Directive (2014/52/EU); Habitats Directive (92/43/EEC) and Birds Directive (2009/147/EC) (see also EPA, 2001; 2004a; 2004b; SI 435/2004; SI 436/2004). Under the SEA Directive, an SEA is mandatory for all energy plans and programmes. The sector must also comply with any and all relevant national transposing legislation, such as the European Communities (Birds and Natural Habitats) Regulations 2011- 2015 as well as relevant national biodiversity and nature conservation legislation including the Wildlife Act, 1976 and the Wildlife (Amendment) Act, 2000.

Developing policy and legislative context:
Biodiversity policy is rapidly developing at the international and European levels to respond to the biodiversity and climate emergency (Dáil Éireann, 2019), and Ireland's next National Biodiversity Plan, to be developed in 2022, will reflect these global, European and national contexts.

The Convention on Biological Diversity is currently undertaking negotiations with its Parties to develop the post-2020 global biodiversity framework and to move towards achievement of the 2050 Vision of "Living in Harmony with Nature". The EU has also recently made calls for a Paris-style (*i.e.* target-driven, legally binding) agreement for biodiversity (European Commission, 2021), and as part of its Green Deal, has adopted its Biodiversity Strategy to 2030, which is intended to support a green recovery following the Covid-19 pandemic. The Strategy's objective is to put Europe's biodiversity on the path to recovery by 2030 and so contains specific actions and commitments, including:

- Establishing a larger EU wide network of protected areas on land and at sea by 2030 (30% on both land and sea, 10% of both being strictly protected)
- Establishing a Nature Restoration Plan, with legally-binding restoration targets
- Unlocking funding for transformative change and a strengthened governance framework.

The Biodiversity Strategy also includes a requirement that Member States ensure that at least 30% of species and habitats not currently in favourable conservation status achieve that status or show a strong positive trend by 2030, and that none show further signs of deterioration.

To support the EU Biodiversity Strategy 2030 and to complement the Protected Areas targets, the European Commission is developing overarching restoration targets that would be legally binding for all Member States. These targets are to enable tangible, measurable and concrete actions that contribute to achieving the overarching goal of halting biodiversity loss and restore degraded ecosystems. Such measurable and time-specific targets for restoration to favourable conservation status for protected habitats and species are not explicit in the Nature Directives; these targets will also encompass habitats and species not protected under the Nature Directives. It is expected that long-term protection of the restored areas will be necessary. These restored areas could therefore contribute towards the EU targets on protected areas.

At the UN High-Level Summit for Biodiversity in September 2020, An Taoiseach signed up to the Leaders' Pledge for Nature which supports the 30/30 targets and calls for an ambitious and meaningful post-2020 global agreement that will address the biodiversity crisis and help bring about the transformative change needed to halt biodiversity loss on a global level.

Ireland has also signed up to the High Ambition Coalition for Nature and People (HAC). The HAC, chaired by France and Costa Rica, builds on the UN Summit for Biodiversity and aims to maintain momentum in mobilizing political will for biodiversity in the lead-up to the next CBD Conference of the Parties (COP15, October 2021). One of the key aims supported by the HAC is the 30/30 target.

- Planning and Development context

This section sets out relevant planning and development policies, legislation and guidance to the wind development sector.

Spatial planning and policy

Adopted in 2018, the National Planning Framework (NPF) is a national planning policy framework that guides Ireland's high-level strategic planning and development, with the aim that population growth will be sustainable, environmentally, socially and economically. Together with the National Development Plan, it guides strategic development and infrastructure development nationally and set the context for the development of the Regional Spatial and Economic Strategies (RSES) by the three Regional Assemblies. These, in turn, take account of and co-ordinate local authority Development Plans, so that all three levels (national, regional and local) align. Local Authority Development Plans, in turn, are required to include Wind Energy Strategies and Local Authority Renewable Energy Strategies. Following the adoption of all three RSES by January 2020, the statutory review process of local authorities' County or City Development Plans was commenced, overseen by the Office of the Planning Regulator. When complete, this process will ensure that all City or County Development Plans are consistent with the national and regional development objectives of the NPF and the relevant RSES.

The Planning and Development Act 2000 (as amended) is the primary planning legislation that influences the sector, setting requirements for regional guidelines, forward planning at the local authority level and development control. The Act sets out requirements for:

- (i) regional planning guidelines;
- (ii) development plans;
- (iii) local area plans;
- (iv) Ministerial guidelines;
- (v) the process of applying for and obtaining planning permission;
- (vi) special requirements for protected structures, conservation areas and areas of special planning control;
- (vii) housing supply;
- (viii) the Office of the Planning Regulator
- (ix) An Bord Pleanála and the planning appeals process;
- (x) planning enforcement processes;
- (xi) strategic development zones and processes;
- (xii) requirements for Environmental Impact Assessment (EIA);
- (xiii) requirements for appropriate assessments;
- (xiv) substitute consent;

(xv) local and State development processes;
(xvi) compensation,
(xvii) amenities;
(xviii) acquisition of land and
(xix) other particular types of development, *inter alia*.

In accordance with section 28 of the Planning Acts, local authorities are required to have regard to any Guidelines issued by the Minister under that section. The Wind Energy Development Guidelines 2006, issued under section 28 of the Planning Acts, advise local authorities to plan for wind energy through the development plan process and to include a statement of its "*policies and objectives in relation to wind energy development and matters it will take into account in assessing planning applications for specific wind energy development proposals*". This plan-led approach also requires the identification of areas considered suitable or unsuitable for wind energy development, and is to be used to inform decisions on such applications.

The guidelines also provide advice on the determination of applications for planning permission (addressed below). In 2013, with input from a range of government department and bodies, SEAI published its Methodology for Local Authority Renewable Energy Strategies (LARES) (SEAI, 2013a) to assist local authorities in the preparation of their renewable energy strategies. The aim of the methodology was to facilitate a consistency of approach in the preparation of LARES, and to assist local authorities in developing robust, co-ordinated and sustainable strategies in accordance with national and European obligations.

Development plans can help to avoid or minimise conflicts, and in particular, to encourage appropriate siting of wind energy developments in areas of potentially low or no conflicts for wildlife, including Hen Harrier strongholds and protected sites. As part of the plan process, local authorities may identify European 2000 sites as "*less favoured areas*" or areas of high sensitivity for wind development in their Wind Energy Strategies, and may discourage wind energy development or consider it to be "*not normally permissible*" within the sites. It should be noted that these categories are indicative and that every wind energy development planning application is to be assessed on its merit, regardless of the categorisation that has been applied to the area within which the development is proposed.

As a result of the consideration of suitable areas for wind energy developments as part of the development plan process, information has been generated regarding the relative sensitivity of constituent parts of each county, as well as county-by-county maps for favoured and less favoured zones for wind energy developments (see individual Local Authority Development Plans). DHLGH has developed Myplan.ie, in collaboration with all planning authorities, to make a wide range of spatial information related to the planning process available to all, including census data, heritage sites and patterns of housing development. SEAI have also funded AIRO (All-Island Research Observatory at NUI Maynooth) to consolidate wind energy maps into an online interactive mapping toolkit, and at the time of writing, a follow-on project is being explored by SEAI to incorporate this resource within a LARES mapping web tool and online viewer.

The Planning Acts also require local authorities, when varying or reviewing Development Plans and the associated land-use/zoning policies, to carry out Strategic Environmental Assessments (SEA) and Appropriate Assessments (AA) of the Plans, as may be required. They transpose the obligations of the EU Habitats Directive (Articles 6(3) and 6(4)) for an Appropriate Assessment (AA) to be carried out where a plan or project is likely to have a significant impact on a European 2000 site. Guidelines on Habitats Directive Articles 6(3) and 6(4) were published by the European Commission (EC, 2001; EC, 2010; EC, 2007/2012) and on the appropriate assessment process by the then Department of Environment, Heritage and Local Government (DoEHLG, 2009; updated in 2011).

*Development Control (*i.e. *planning for individual wind energy developments)*
As mentioned above, the Planning Acts and Regulations set out the legislative context for planning permissions for individual wind energy developments.

To obtain consent for individual wind energy developments, applicants need to submit a Natura Impact Statement (NIS) (DoEHLG, 2009), if one is deemed necessary by the planning authority. *i.e.* if they have determined that significant effects may arise on a European site as a result of the proposed development. An NIS is to be prepared by ecological experts in order to allow the planning authority to complete the AA process and their determination as to whether adverse effects on the integrity of European sites may or will arise.

The need to apply the precautionary principle in appropriate assessments has been enshrined in ECJ case law (*e.g*. where effects may arise but have not been proven) (*e.g.* Waddenzee Judgment (ECJ, 2004). Public authorities shall give consent to a plan or project, or adopt a plan or project, under Article 6 (3) of the Habitats Directive, only after having determined that it shall not adversely affect the integrity of a European site; furthermore, appropriate assessments should "*include complete, precise and definitive findings and conclusions that are capable of removing all scientific doubt as to the effects of the proposed development on … [sites] concerned*" (High Court, 2014).

If adverse effects are predicted or cannot be excluded, (even with proposed mitigation), the plan or project may proceed under Article 6(4) of the Habitats Directive, but only where there are:

- Imperative Reasons of Over-riding Public Interest (IROPI), including those concerning human health, public safety and beneficial consequences of primary importance for the environment, or those of a social or economic nature
- Where there is an absence of alternative solutions, and
- Where compensation measures for the adverse effects arising have been identified and put in place (DoEHLG, 2009; EC, 2007/2012).

Decisions of the local planning authorities to grant permission for wind energy development may be appealed to An Bord Pleanála. 'Strategic' developments must seek planning consent directly from An Bord Pleanála, through the Strategic Infrastructure Development (SID) process, rather than from the relevant local authority. This may include some wind energy developments *e.g.* installation of a wind energy development with more than 25 turbines or having a total output greater than 50MW (Schedule 7 of the Planning and Development Regulations, 2001).

On those occasions where planning permission or development consent is not required for the construction or reconstruction of a generating station to supply electricity to final customers, the Commission for Regulation of Utilities (CRU) grant or refuse authorisations, following the assessment of an associated application. In such cases, the CRU is responsible for the undertaking of any required appropriate assessment (CRU, 2020).

Guidance to support the development and assessment of wind energy developments

The then Department of Environment, Heritage and Local Government published extensive guidelines for the development of wind energy developments (DoEHLG, 2006) which includes natural heritage considerations. The guidelines set out a framework for wind energy development and planning related matters including, among other things, environmental impacts, and recommend early identification (via GIS mapping) of natural heritage designations. Such designations do not necessarily preclude wind energy development applications, but require that obligations under the EU Birds and Habitats Directives must be met, including that the planning authority is satisfied that there will be no adverse effects on the integrity or conservation objectives of any designated site from any proposed development, prior to consent.

In accordance with planning legislation, it is also requirement for an EIA to be undertaken for wind energy developments that will have more than five turbines, or a total output greater than 5MW. Certain sub-threshold developments also require an EIA wherever the planning authority or An Bord Pleanála considers that the development would be likely to have significant effects on the environment. In 2018, the then Department of Housing, Planning and Local Government published updated section 28 Guidelines for planning authorities and An Bord Pleanála on carrying out EIAs (DHPLG, 2018), to take account of the 2014 amendments to the EIA Directive (Directive 2014/52/EU). The 2014 EIA Directive retained wind energy development in its Annex II which means that the requirement for an EIA is determined at the national level, either on the basis of thresholds/criteria or a case by case examination, having regard to the criteria set out in Annex III. In addition, Recitals 7 and 13 of the EIA Directive now oblige the consideration of the impacts of climate change on a project as well as the impacts of a project on climate, as well as on biodiversity.

In June 2017, DHPLG and DCCAE published a “preferred draft approach” to the Review of the 2006 Wind Energy Development Guidelines. This approach focused on issues relating to Sound/ Noise, Visual Amenity Setback, Shadow Flicker, Consultation Obligations, Community Dividend and Grid Connections. DHPLG and DCCAE then published draft Wind Energy Development Guidelines, incorporating the “preferred draft approach”, for public consultation in December 2019. Following consideration of the submissions received, and any further revisions to the draft as required, the finalised Guidelines will be published.

Informed by the DoEHLG guidelines (2006), WEI (then IWEA) produced their own industry guidelines for the sector which focus on all stages of the development process from initial feasibility studies to operational, decommissioning and repowering (IWEA, 2012). These guidelines are not required to be taken into consideration by a developer or a consenting authority.

Locally and at a European level, additional supporting guidance on the preparation of EIA and AA has also been published which ensures regular updates to practitioners (*e.g.* EPA, 2002; EPA, 2003; EU, 2010 – 2016). Most recently, the European Commission has produced an extensive revision of its guidance document on wind energy developments and EU nature legislation, in recognition of the need to tackle climate change, to address growing pressures on and loss of biodiversity, to reflect most recent insights and to develop good practice so that respective policy goals and targets can be reconciled (European Commission, 2020b).

In Ireland, the Forest Service (2011) has also published ancillary guidance for wind energy development in afforested sites, and departmental policy statements show general support for renewable energy policy; *e.g.* the Department of Agriculture, Food and the Marine has published its Climate Change Sectoral Adaptation Plan for the Agriculture and Forest sectors (*e.g.* DAFM, 2019a and 2019b).

There are no specifically Irish-prepared ornithology guidelines to inform surveys for the development of wind energy in Ireland. Specific direction has been provided by NPWS (2002) for Hen Harrier surveys to inform impact assessments for wind energy development. This included the recommendations for 500m wind energy development buffers and wider hinterland surveys up to 5km for Hen Harriers. Furthermore, recommendations for systematic sampling to quantify site usage between April and August via vantage point observations were given (based on Madders, 2002), as well as consideration of cumulative effect of other wind energy developments in the area. Further guidance will be prepared by NPWS as an action of the HHTRP.

Percival (2003) reviewed available knowledge on the effects of wind energy developments on birds, particularly in relation to potential issues in Ireland, including disturbance-related research. This work also set out to provide a methodology for assessing the effects of wind energy developments on bird species. It addressed:

- baseline data collection,
- evaluation of sensitivities,
- establishing the magnitude of possible impacts,
- determination of significance of possible impacts,
- mitigation and
- cumulative assessment.

The review recommended the adoption of British Wind Energy Association (BWEA) and Scottish Natural Heritage (SNH, now known as NatureScot) guidance with Ireland-specific adaptations. This study also set out a number of criteria which could be used to assess the ornithological sensitivity the site being assessed and the species involved *e.g.* it considered that SPA selection species (or Species of Conservation Interest/SCI) should be considered 'very high' sensitivity. On the basis of its ecological characteristics (where it is not an SCI species), Hen

Harrier was classified as 'high' sensitivity. Thus, in Ireland, in the SPAs for which Hen Harrier is an SCI species, it would be considered to be 'very high' sensitivity, and where it occurs outside the SPA Network, 'high' sensitivity.

There is also a suite of published research on wind energy developments and birds (see Chapter 2) and Wilson *et al.* (2015) has reviewed guidelines in use in the UK and elsewhere in Europe. In Scotland, a detailed framework for ornithological interactions has been set out (SNH, 2000; 2006; 2011) and frequently, independent ecologists operating in other jurisdictions, including other constituent parts of the UK (England, Wales and Northern Ireland) and in Ireland, may use or adapt SNH (now known as NatureScot) guidelines during their assessment and implementation of wind energy development planning processes. In addition to best practice guides for construction and decommissioning, these guidelines include recommendations on specific surveys, methods, seasons, assessment, avoidance, disturbance, repowering, habitat management, cumulative assessment, SPA connectivity, carcass searches, power lines, meteorological masts and are available online on the NatureScot website (see also review in Wilson *et al.*, 2015).

In the absence of specific Hen Harrier (or ornithological) guidelines in Ireland, the generic ornithology guidance provided by DoEHLG (2006) and IWEA (2012) and on appropriate assessments required for development within SPAs (DoEHLG, 2009; EU, 2011), along with the EU's guidance on wind energy developments and Natura 2000 (European Commission (EC), 2010), most recently updated in late 2020 (European Commission, 2020b) comprise best available guidance in Ireland.

Further to statutory and other guidance, there are also ancillary guidance tools available that can be used to inform wind energy development planning and associated ornithological requirements. These include the wind energy development sensitivity mapping tool, available via the National Biodiversity Data Centre's Biodiversity Maps portal and funded by SEAI. The primary research for this tool was undertaken in 2012, with an outline method and policy development protocol (Tierney *et al.*, 2012). The more detailed secondary report and assessment tool (McGuinness *et al.*, 2015) also provided a research output (and spatial planning tool) to inform wind energy development sensitivity for Hen Harriers and 21 other bird species for which spatial data were available. It has been developed into an AA and SEA screening tool by AIRO/NIRSA at NUI Maynooth, and SEAI is also funding its further development into the LARES data viewer and web tool.

Ireland's wind energy resource

Ireland has a relatively high wind resource that typically increases with increasing altitude (SEAI, 2013b; SEAI online Wind Atlas). Therefore, turbines have perhaps, historically, been more likely to be located in upland areas. Wind energy developments can theoretically be developed spatially anywhere in Ireland although spatial optimisation, particularly for wind output (Rasuo and Bengin, 2010) and other environmental constraints, is desirable. Because of dispersed historical development in Ireland and rural settlement patterns in particular, as well as related considerations that require wind energy development to be set away from settlements, very large swathes of the country are considered to be effectively unsuitable for wind energy development.

Newer and larger turbines may be less restricted by altitudinal requirements (*i.e.* installation in windier, upland areas) as they are now larger and can exploit wind resources at lower levels more easily. Thus, they can (theoretically) be installed at lower elevations and still harvest wind resources previously only obtained at higher elevations. However, similarly-sized turbines at lower levels will, on average, deliver lower energy yields than those in upland locations (SEAI online Wind Atlas; J. McCann, pers. comm.).

At the time of designation (2006), wind energy developments were located within the boundaries of four of the six Hen Harrier SPAs) and as of 2016, turbines had also been permitted in or in proximity to three SPAs post-designation (see Chapter 3). There are currently no explicit prohibitions on wind energy development within SPAs. However, as already mentioned, there is a requirement to undertake an appropriate assessment to ensure the development does not affect the integrity of the SPA.

A database of spatial and descriptive statistics of wind turbines greater than 0.1MW in Ireland (SEAI, unpublished; J. McCann, pers. comm.) confirms that the first wind energy development was erected in Ireland in 1992 (Co. Mayo; Figure 4). After a short hiatus between 1993 and 1996, the number of turbines increased annually, although the numbers of turbines connected varies between years (Figure 5). The average capacity installed annually between 2008 and 2017 was 258 MW. More recently, in 2019 alone, 461 MW was installed, bringing the total installed wind capacity to 4,137 MW (SEAI, 2020).

There are two databases in which information on wind energy in Ireland is collated *i.e.* the Transmission System Operator (TSO) database held by Eirgrid and the Distribution System Operator (DSO) database held at ESB Networks. WEI and SEAI present information on wind power in Ireland, informed, in part, by these databases. At the global level, there are also sources of relevant data (*e.g.* The Wind Power website). Both the TSO and DSO databases have two separate sub-databases for the connected (or energised) wind energy projects, as well as the contracted projects that have grid connection offers but have not yet been constructed, energised or connected. These databases do not necessarily provide information on the numbers of installed turbines or individual turbine capacity but rather the Maximum Export Capacity (MEC) upon which connection agreements are made. A single wind energy development may have several connection agreements and associated reference numbers for energy export. Figure 5 illustrates the connected wind-energy resources in Ireland up until 2016 (2,780MW).

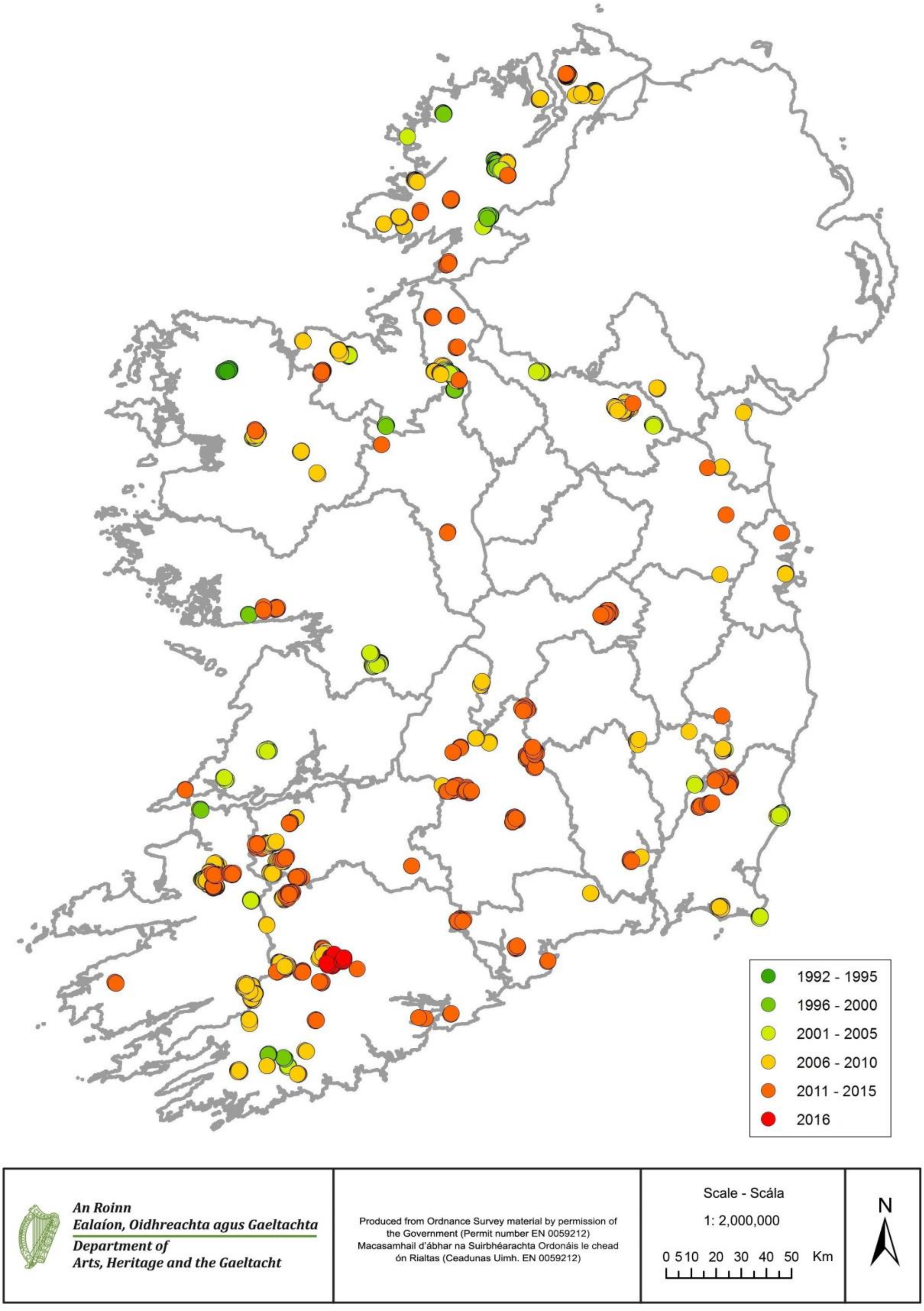

Figure 4. The cumulative distribution of terrestrial turbines connected in Ireland (1992 – 2016).

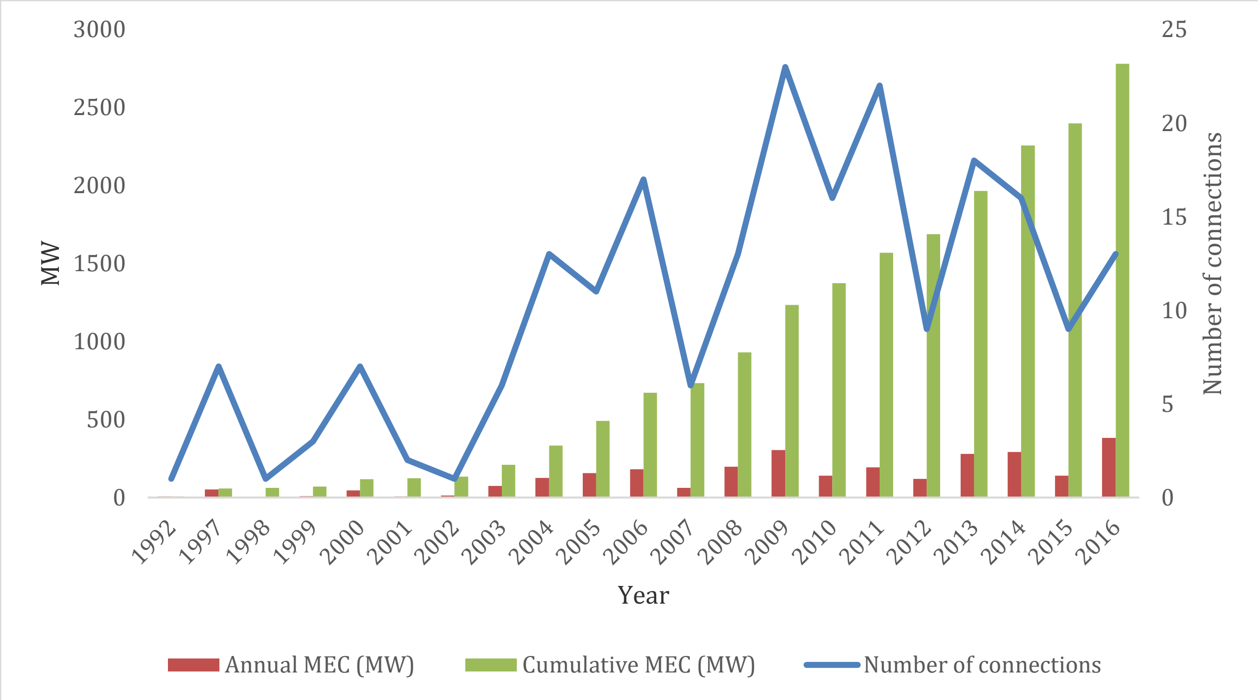

Figure 5. The annual and cumulative connected MW in Ireland between 1992 and 2016 (derived from statistics collated by ESB and TSO).

The NECP, submitted in Summer 2020, outlines estimated trajectories for the deployment of renewable energy technologies in Ireland, including renewable electricity technologies, taking into account the policies outlined in the 2019 Climate Action Plan (the With Additional Measures, or WAM, scenario) (DCCAE, 2020). In this scenario, the deployment of onshore wind is estimated to increase to 7.5GW by 2030 and to 8GW by 2040. The NECP trajectories will be reviewed in light of the policies adopted pursuant to the 2020 Programme of Government and ambitions of the European Green Deal, particularly the commitment to increased deployment of offshore wind and the increased ambition for greenhouse gas reductions and renewable energy penetration.

The overall trend of increasing power supply to meet renewable electricity targets takes into account the repowering of existing onshore wind energy developments (SEAI, 2011). The repowering of wind energy developments is expected to become increasingly relevant in coming years given the 20-30 year life-span of earliest developments. It also receives particular attention in the recast Renewable Energy Directive (2018/2001/EU) and the Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action, which requires Member States to facilitate the repowering of existing renewable energy plants with simplified and swift permitting processes that take no longer than one year (Article 16 (6)).

Wind energy development performance declines with age, and the rate of decline may be influenced by a number of factors, including terrain, weather, fleet vintage, as well as regulatory, policy and contractual factors (Hamilton *et al.*, 2020). The repowering of existing sites, where permissible, will be able to capitalise on recent technological advances, efficiency and increased power output of newer turbines (Herbert *et al.*, 2007; Sarkar and Behera, 2012). This will likely mean installation of larger and greater-output turbines over time, although the largest turbines (>7.5MW, with the largest offshore turbine 12MW, as of 2020) are proposed primarily for offshore use. Maximum onshore turbine height will be influenced by the establishment of a setback distance, set at four times tip height, subject to a mandatory minimum of 500m, as set out in the "preferred draft approach" and the Draft Wind Energy Development Guidelines (DHPLG, 2019).

Developing a Wind Energy Development Application

The installation of wind energy development in Ireland typically involves several phases:

(i) pre-application feasibility and suitability;
(ii) research and assessment;
(iii) planning application and decision-making;
(iv) construction;
(v) operation and
(vi) decommissioning, renewal (*i.e.* life extension) or repowering.

Stage (i) Pre-application feasibility and suitability: It is recommended that an extensive suitability and feasibility assessment be undertaken before a planning application is submitted (known as the "pre-application stage") (DoEHLG, 2006). Such assessments are a judicious use of resources to explore technical, economic and site-specific options, and involve early screening of high-risk or poorly-sited developments before any further financial investment is committed.

Stage (ii) Research and assessment: It is likely to be necessary to undertake research, survey and assessment in order to prepare for, amongst other things, the requirements of an Environmental Impact Assessment (EIA) and/or for an Appropriate Assessment.

Stage (iii) Planning application and decision-making: The applicant submits their application to the relevant planning authority, along with the Environmental Impact Assessment Report and Natura Impact Statement, if required. Applications are examined with reference to, *inter alia*, their impact on designated sites, nature conservation and taking into account the provisions of domestic and European legislation. The planning authority must refer all planning applications that might have significant effects in relation to nature conservation to NPWS-DHLGH. NPWS prepares and submits observations to the planning authority, which then concludes its Appropriate Assessment, and makes a decision on the application. The findings of the Appropriate Assessment must be taken into account in its decision-making.

The planning authority may set a series of planning conditions, including risk mitigation measures as part of the planning consent. Provided sufficiently robust information is available to inform the assessment and review by the planning authority, these conditions should provide for mitigation for any residual risk at all stages of wind energy development construction, operation and decommissioning.

In addition to planning consent, it is necessary to secure a grid connection (in order for a wind energy development to be able to export power to the national grid) and to agree the route and type of transmission (*e.g.* underground cables or overhead power lines). Details of the grid connection must also form part of the planning approval process, where EIA/AA is required, in order to ensure that the impact of the whole project is considered. Connection offers from grid operators can be obtained prior to planning consent. Grid connection contracts are typically in place prior to commencement of construction.

Stage (iv) Construction: Construction can involve the creation of roads (typically hard-fill or floating road designs); turbine bases and hard-standings; erection of turbine towers, nacelles and blades; construction of operation/control rooms; construction/erection of grid connection infrastructure (*e.g.* underground cabling or overhead power lines). Planning consents also have specific requirements pertaining to the management of environmental risk during construction. For example, there may be a requirement to manage temporal constraints such as bad winter weather, with the elevated risk of siltation (run-off), or disturbance to breeding birds during the summer, or to have an Ecological Clerk of Works on site, to oversee the works and to ensure compliance with ecological mitigation measures.

Construction activities typically involve a relatively large work force and associated vehicles, cranes and other machinery to build the necessary infrastructure. Construction activities may also require the creation of borrow-pits, quarries, sediment ponds and temporary compounds; road widening and improvement works on the approaches to the site; installation of drainage infrastructure and waste disposal locations for material such as spoil from excavation works. Construction activities may also include habitat modification such as felling of trees (*e.g.* key-hole felling), habitat creation or restoration. Direct land-take by wind turbines may be relatively small compared to the entire wind energy development site, but the ecological impacts arising from the entirety of the development, *e.g.* through construction activities *etc.*, may affect a much wider area. The impacts of all these activities are to be assessed in the relevant ecological assessments.

Stage (v) Operation: The primary operational phase of a wind turbine or wind energy development may extend to 20-30 years, as directed by the planning consent. The scope of a full operation and maintenance contract includes the generating plant (*i.e.* turbines) and the entire wind energy development site, including access tracks, auxiliary buildings and electrical infrastructure. For the most part, day-to-day maintenance and operation of the site is undertaken either remotely and/or by a small number of site personnel and associated vehicles. Site operation involves one or a limited number of personnel attending the site on a daily basis, or occasionally, in order to undertake routine site and/or infrastructure inspections or condition assessments. Some site compounds may be used as operational bases for regional staff and thus, regular activity may occur. This may present other novel sources of disturbance to wildlife. For many wind energy developments, controls rooms are located at the electrical substation, commonly close to the entry point to the development, at a lower elevation, and not within the wind array. Remote monitoring involves only intermittent visits by personnel, when operational issues require their attendance.

Operations staff or technicians may need to respond either remotely or locally to maintenance notifications in order to diagnose the cause of the notification and reset, if needed. Such responses may be required around the clock, depending on its cause, though it is understood that most can be addressed remotely. There may be human and vehicular activity associated with scheduled (*e.g.* quarterly or annual) maintenance inspections, service monitoring and repairs. There may also be a requirement for attendance of heavy goods vehicles or cranes in order to undertake more substantial repairs or maintenance; these are most likely to be required when major turbine components reach "end-of-life" (typically, more than 10 years into service). Larger scale operations, *e.g.* to remove/ replace turbines or extensive road repairs, may cause disturbance to species or habitats outside the primary construction periods.

The operational phase may also include ongoing or intermittent monitoring, reporting and management activities *e.g.* bird surveys, collision mortality (carcass searches), environmental management (*e.g.* habitat management). This phase may also be subject to environmental, health and safety and operational guidelines, which may vary between sites and operators.

Stage (vi) Decommissioning, Renewal or Repowering: Decommissioning may be included as a planning condition for a wind energy development but increasingly, repowering of existing sites may extend its lifetime. Factors that may drive the requirement for decommissioning include time-bound constraints on manufacturer warranties (and the associated risks), reliability (which may decrease over time), maintenance issues and efficiency (Verma *et al.*, 2015).

Following the cessation of a wind energy development operation, decommissioning involves the dismantling and removal of above-ground equipment (masts, turbines and foundations) from the site and all associated structures (including any access roads) are removed and vegetation reinstated. These activities are usually conditioned to be undertaken within three months of decommissioning (*e.g.* An Bord Pleanála, 2016). There is, as yet, little experience of this in Ireland but more detailed studies and reviews have been undertaken in Scotland (Welstead *et al.*, 2013).

Wind energy developers may also apply for permission to renew permission for a wind energy development. Renewal entails the seeking of planning permission to continue using the wind energy development as constructed, beyond the time limit specified in the original planning permission (if such a condition is in place) and may include replacing components (up to and including a wind turbine/s) of the wind energy development on a like-for-like basis.

Repowering entails entails the removal of the existing equipment and the seeking of planning permission for the installation of new wind turbines and any ancillary works required within the wind energy development site. As existing wind energy developments near the end of their operating lives, applications for repowering are steadily increasing. In some cases, the wind energy developments will be repowered due to rapidly evolving technology and changing financial incentives. In many cases, applicants will seek to install larger turbines when repowering an existing site.

Applications for repowering will need to be accompanied by further and more up-to-date surveys and ecological/environmental assessments in order to inform the associated planning decisions. The effects arising may differ to those of the original project as risks may shift from one receptor group to another (European Commission, 2020b). Specific guidance on the approach to be used in the ecological assessment of repowering to inform AAs and EIAs may also be of benefit. Applications for repowering should be considered on a case-by-case basis by the planning authority taking into account all relevant legislation, policy and guidance, including the updated Wind Energy Development Guidelines to be issued by DHLGH.

CHAPTER 2: INTERACTIONS BETWEEN WIND ENERGY DEVELOPMENT & THE HEN HARRIER IN IRELAND

Introduction

This chapter outlines the potential interactions between wind energy development and the Hen Harrier in Ireland. It provides an overview of such interactions with birds generally, as well as the breeding and non-breeding Irish Hen Harrier population, within and outside the SPA network. It sets out the variety of interactions that may arise and then relates these to various aspects of Hen Harrier ecology. This review is largely based on scientific publications and reports, the majority of which are from peer-reviewed sources.

Wind energy development -bird interactions

Wind energy development interactions with birds can have lethal or non-lethal effects. Wind turbine construction and/or development work present three main risks to birds (Desholm, 2006), namely:

1) direct mortality due to collision with the turbine blades, nacelles, towers and/or ancillary wind energy development infrastructure (*e.g.* overhead power lines, if used; meteorological masts) (Barrios and Rodriguez, 2004; Band *et al.*, 2007; Drewitt and Langston, 2008; Bellebaum *et al.*, 2013);

(2) loss of breeding and/or foraging habitat, due to the footprint of construction, or fragmentation of breeding, wintering or foraging habitats (de Lucas *et al.*, 2008; Pearce-Higgins *et al.*, 2009a; Fijn *et al.*, 2012; Zimmerling *et al.*, 2013), and

(3) displacement of birds as a result of increased disturbance (Devereaux *et al.*, 2008; Fielding and Haworth, 2010; Fijn *et al.*, 2012), and/or loss of suitable habitat, and barrier effects caused by turbine arrays (Barrios and Rodriguez, 2004; Desholm and Kahlert, 2005; Masden *et al.*, 2009).

These potential effects are not mutually exclusive and may interact with one another to increase or decrease the severity of the overall effect. For example, reduced occurrence of a species on a site, caused by habitat loss, may decrease their risk of collision. Similarly, the absence of an avoidance response in some species or in individual birds may increase their collision risk (Drewitt and Langston, 2006; McGuinness *et al.*, 2015), and subsequent mortality.

There are a number of research studies and reviews available on the interactions between wind energy developments and raptors, in particular arising from studies over the last 25 years in Spain, USA, the Netherlands, Germany and Belgium (Crockford, 1992; Langston and Pullan, 2003; Stewart *et al.*, 2007; Carrete *et al.*, 2009; Wang and Wang, 2015; Schaub *et al.*, 2020).

Wind energy developments and collisions

The key concern of direct mortality and injury to birds through wind energy development-mediated collision is widely studied. The mortality effects on birds can be variable and may be affected by:

- season (Barclay *et al.,* 2007; Minderman *et al*., 2012);
- topography (de Lucas *et al.,* 2012; Katzner *et al*., 2012);

- turbine metrics such as height, design and age (Orloff and Flannery, 1992; Osborn *et al.*, 2000; Smallwood & Thelander, 2004; de Lucas *et al.*, 2008);
- spatial arrangement of the wind energy development (Ferrer *et al.*, 2012; Zwart *et al.*, 2016; Schaub *et al.*, 2020);
- weather conditions (Winkelman 1992; Drewitt and Langston, 2006; Kunz *et al.*, 2007; Larsen and Guillemette, 2007; Lawrence *et al.*, 2007; Drewitt and Langston, 2008; Farfán *et al.*, 2009);
- repowering (SNH, 2014);
- specific species' vulnerability or morphology (Barrios and Rodriguez, 2004; Smallwood *et al.*, 2009);
- species' abundance and distribution (Fielding *et al.*, 2006; Douglas *et al.*, 2011; Carrete *et al.*, 2012); and
- value or attractiveness of surrounding habitats (Larsen and Madsen, 2000; Walker *et al.*, 2005; Martinez-Abrain *et al.*, 2012).

The statistical relationship between bird mortality and turbine design is complex (Hötker *et al.*, 2006; Barclay *et al.*, 2007; Stewart *et al.*, 2007; Pearce-Higgins *et al.*, 2009a; 2012; Ferrer *et al.*, 2012; Thaxter *et al.*, 2017). It is also widely recognised that a species' population dynamics can be affected by mortality that may be additive (*i.e.* adding to natural mortality) or compensatory (*i.e.* substituting for natural mortality) (Cole and Dahl, 2013; Dahl *et al.*, 2013). Wind energy development collisions may operate in combination with other mortality factors, thereby exacerbating population declines or low/declining rates of population growth. This is of particular concern given the likelihood of extensive increases in numbers of turbines, both nationally and globally, in order to meet growing renewable energy targets.

Overhead lines may also elevate collision risk and/or occurrence of collisions (Hagen *et al.*, 2007; Doherty *et al.*, 2008) and may cause avoidance or displacement over a wider area *e.g.* declining habitat use over 600m, as recorded by Braun (1998). Overhead power lines and associated infrastructure (*i.e.* pylons or poles) may also act as perching locations for some species (Manosa, 2001; Smallie and Virani, 2010), including nest predators such as corvids (Lammers and Collopy, 2005), as well as causing electrocution (Tryjanowski *et al.*, 2013).

Poorly-sited developments can result in extensive mortality *e.g.* Smóla (Norway), Altamont Pass (California) and Tarifa (Spain) (Osborn and Schillinger, 1996; Hunt, 2002; Follestad *et al.*, 2007; de Lucas *et al.*, 2008; Telleria, 2009a; b). Whilst site-specific mortality can be increased by poorly-sited turbines, it may be lower than other types of mortality such as persecution (*e.g.* shooting or poisoning), predation or other types of collisions (*e.g.* vehicles, towers, buildings, power lines) (Langston and Pullan, 2003). However, impacts at the population level may be more marked in the cases of poorly-manoeuvrable, rare, long-lived species (Carrete *et al.*, 2009; Cole and Dahl, 2013). Effects may be particularly marked in those species which have low breeding productivity (Carrete *et al.*, 2009; Cruz-Delgado *et al.*, 2010), of which the Hen Harrier is one. There may also be a higher likelihood of effects on migrants (Masden *et al.*, 2009; Telleria, 2009b), particularly where mortality occurs in one part of the migratory or seasonal range. This, then, may have effects well beyond the site of the actual collision (Katzner *et al.*, 2015).

The potential effects of repowering on bird mortality rates appears to be variable (Stewart *et al.*, 2007; Drewitt and Langston, 2008 contra Smallwood and Thelander, 2004; Barclay *et al.*, 2007). Some studies have concluded that there is no compelling evidence that repowering (*i.e.* increasing the capacity) of older turbines will change the collision risk for birds (Stewart *et al.*, 2007; Drewitt and Langston, 2008). Thaxter *et al*. (2017) conclude from their review study across a range of bird species, that, per energy output, collision risk may be reduced, if fewer larger turbines are installed, rather than many smaller ones. They highlighted that more research is needed to understand the relationship between collision risk and turbine size, and its variation between the habitats in which the turbines are located. The ecological effects of repowering will need to be considered on a site-by-site and species-by-species basis (European Commission, 2020b) as to whether it would result in a change to predicted collision risk.

Collision risk at wind energy developments is therefore a complex interaction between various species' characteristics and occurrence, and environmental and wind turbine/wind energy development factors (see Wilson *et al.*, 2015).

Hen Harriers and collisions

While low-medium risks of collision mortality has been identified by Whitfield and Madders (2006), Hen Harrier collisions have been reported, including in Spain (Lekuona and Ursúa, 2007 (n = 1); Northern Ireland (Scott and McHaffie, 2008; Co. Antrim; n = 1); Scotland (RSPB, 2012, Perthshire; n = 2) and Ireland.

In Ireland, as part of their review and study of flights behaviour, Wilson *et al.* (2015) recorded that:

- (i) during sky dancing displays, Hen Harriers achieved flight heights that put them at potential risk from wind turbines;
- (ii) average flight heights of adult Hen Harriers did not change in response to wind turbine presence, although it is possible that birds altered their flight height in the proximity of individual turbines;
- (iii) adult male Hen Harriers spent up to 12% of their flight time at wind turbine rotor swept height; and
- (iv) newly-fledged juvenile Hen Harriers spent the majority of their time below turbine rotor sweep height, in and around the nest area.

Overall, it was concluded that the risk of direct collision with wind turbine rotors was low (Wilson *et al*., 2015). However, since that study's conclusion in 2015 and even in the absence of robust carcass searches, NPWS-DHLGH has received reports (including photographic evidence) of one "possible" case and three "probable/confirmed"[1] incidences of Hen Harrier mortality caused by turbine strike.

Mortality of the allied Northern Harrier (*Circus hudsonius*) (Etherington and Mobley, 2016), (which was until recently considered to be the same species as the Hen Harrier) has also been recorded, with six collisions reported at Altamont Pass Wind Resource Area (APWRA), California (situated on a major bird migratory route with high concentrations of raptors) and Foote Creek Rim, Wyoming (Erickson *et al.*, 2001; Johnson *et al.*, 2001; Kingsley and Whittam, 2005). There were three recorded by Smallwood and Thelander (2004) over five years, and seven reported between 1989 and 2007 by Smallwood and Karas (2008), although some of these studies appear to report on the same data over different time periods. Three Northern Harrier collisions were also reported by Derby *et al.* (2008) at Buffalo Ridge, Dakota, USA.

In addition to the relatively small number of collisions occurring, many studies show that there does not appear to be a link between Hen Harrier abundance and collision levels, or those of Northern Harriers (Johnson *et al.*, 2000; Stewart *et al.*, 2005; Mabey and Paul, 2007; Whitfield and Madders, 2006). Mortality of harriers may also be disproportionately lower than other raptors (Drewitt and Langston, 2008). Hen Harriers may be at lower risk of collision due to the majority of low-elevation flights undertaken by the species (Madders, 2000; Whitfield and Madders, 2006; Band *et al.*, 2007), which does not normally predispose them to flying within the rotor swept zone, and avoidance responses (Garvin *et al.*, 2011). Wilson *et al.* (2015) suggested that collision risk may be affected by the proximity of the nest and during breeding displays.

A recent study examining flight behaviours of Montagu's Harriers, using three-dimensional GPS tracking data to investigate collision risk of breeding males with wind turbines, found that only 7.1% of flights were within the average rotor height range (RHR; 45-125m), with birds spending as much as 8.2 h per day in flight, more than Hen Harriers in the same study area (4-6 h/day for males during the breeding season) (Schaub *et al*., 2020). Avoidance of turbine towers was demonstrated, with a distinct reduction of flight activity near turbines. This analysis estimated that any repowering of wind energy developments in the study area (where tracked birds visited nine wind energy developments in total), using low-reaching modern turbines (RHR 36-150m), could more than double the risk of collision for Montagu's Harriers.

With respect to Hen Harrier, repowering of old wind turbines with larger models may move the rotor swept area above their typical foraging altitude. Between 1992 and 2014, the average height of the lower edge of the rotor swept area doubled. Thaxter *et al.*'s (2017) review study

[1] A determination of cause of death of any remains discovered near a turbine or wind energy development footprint is made based on a review of the available evidence. This includes:
- proximity of the specimen when found, relative to a wind turbine;
- a detailed physical examination of the remains by an expert *e.g.* veterinary surgeon and x-rays to ascertain whether injuries sustained would be consistent with a turbine collision.
Such cases where the nature of the physical trauma *i.e.* fractures and/or severed body parts are consistent with a turbine strike are deemed 'probable/confirmed' for reporting purposes. Where a turbine strike cannot be discounted as cause of death, such incidents are recorded as 'possible'.

identified a strong positive correlation between turbine capacity (MW) and bird collisions per turbine, indicating that fewer larger turbines should be installed to minimize collisions.

Wind energy developments and habitat loss and fragmentation

Construction of hard surfaces, *e.g.* for roads and turbine foundations *etc.,* cause direct habitat loss. The construction of access roads may also increase fragmentation of habitats (Trombulak & Frissel, 2000) that may be important for bird species but it may also attract other species *e.g.* by providing novel linear features which harriers may utilise for foraging (M. Ruddock, personal observation). Overhead power lines and any associated vegetation clearance can similarly influence small mammal (prey) populations (Osbourne *et al.*, 2005) and create fragmentation or barriers to movement (Andrews, 1990; Pruett *et al.*, 2009a and 2009b; Hagen *et al.*, 2011).

Wind energy developments and displacement of bird species, including Hen Harrier

Displacement and/or disturbance can potentially occur in three phases of the wind energy development's lifespan: firstly, during construction phase; secondly, during the post-construction phase and finally, in the decommissioning or repowering phase. The former and latter will occur over a short temporal period (weeks – 18 months) whilst the operational phase will occur over several years *i.e.* the period for which it is operational (20-25 years). Issues are also most likely to arise where spatial and/or temporal interactions occur between nesting, foraging or roosting habitats and wind energy developments and activities.

Displacement from breeding, wintering or foraging areas (effectively, a loss of habitat) can occur as a result of both direct and indirect effects at wind energy developments. Direct bird displacement may be caused either through direct habitat loss, perturbation or changes to habitats *i.e.* loss of nesting or roosting habitat. Indirect displacement by wind energy development can be manifested through behavioural avoidance by birds because of associated disturbance (Langston and Pullan, 2003; Dahl *et al.*, 2013) and/or modification of foraging habitats, thereby affecting their utility (Arroyo *et al.*, 2009).

Operations (once-off or recurring) that have the potential to disturb nesting Hen Harrier (see Chapter 1) during pre-construction, construction and operational phases of wind energy developments include the following, though not every wind energy development will involve all those listed (*e.g*. tree felling, overhead power lines):

(i) mechanical site (vegetation) clearance;
(ii) timber felling (clearfell), extraction and removal;
(iii) mechanical extraction and drilling for cabling;
(iv) mechanical extraction for creation of foundations;
(v) road construction (and associated developments);
(vi) mechanical piling / drilling for turbine bases;
(vii) the erection of fences;
(viii) the erection of power lines, poles and associated rigging;
(ix) operational site monitoring activities;
(x) operational site maintenance activities; and
(xi) operational habitat management activities.

Indirect effects can also be due to behavioural avoidance of actual turbines at a small scale (*i.e.* individual turbine) or a wider 'barrier effect' at wind energy development(s) level (Hotker *et al.*, 2006; de Lucas *et al.*, 2004; Sugimoto and Matsuda, 2011; Plonczhier and Simms, 2012; Humphreys *et al.*, 2015), where preferred flyway routes may be altered, particularly for migrating birds (Masden *et al.*, 2009; Telleria, 2009a).

A wide range of conclusions have been drawn in relation to wind energy developments and their displacement effects on birds, including that:

- it does not occur or its effects are negligible, acting at a small-scale (Madders and Whitfield, 2006; Devereux *et al.*, 2008; Douglas *et al.*, 2011; Haworth and Fielding, 2012);
- it has negative impacts (Pearce-Higgins *et al.*, 2009b); and
- the direction of observed or predicted effects are complex interactions between site-specific and species-specific metrics (Drewitt and Langston, 2006; Pearce-Higgins *et al.*, 2009a; 2012; Garvin *et al.*, 2011; Dahl *et al.*, 2013; Thaxter *et al.*, 2015).

The direct habitat loss due to the footprint of construction is likely to be a relatively small area of land, with a wider behavioural effect caused by avoidance likely across a greater area (*i.e.* the zone of influence). The key metric for displacement is a spatial response *i.e.* avoidance of wind energy developments or turbines by a specified distance (Whitfield *et al.*, 2008), although it is recognised that this spatial response can be highly variable between species (Marques *et al.*, 2014) and may be highly individualistic.

Reviews and empirical studies, measuring pre- and post-construction abundance and distribution, show that displacement exhibits considerable intra-specific variation, and where it does occur, it may range from 50m to 1,000m. Some species may not be affected (Douglas *et al.*, 2011) but the effects on others may, however, extend to a much greater distance (see Ruddock and Whitfield, 2007; Whitfield *et al.*, 2008).

In their field study, Fernández-Bellon *et al.* (2019) found that total bird densities were lower at wind energy developments than at control sites, and that the greatest differences occurred close to turbines. In addition, it was found that the scale and intensity of the displacement effects of wind energy development on upland birds depends on bird species' habitat associations and that the observed effects are mediated by changes in land use associated with wind energy development construction.

Pearce-Higgins *et al.* (2009) found in field experiments that there was no relationship between displacement and turbine size (range 30m – 70m; 8.4 MW – 97 MW) or power, whilst in their meta-analysis review, Stewart *et al.* (2005, 2007) found that there does not seem to be an inter-relationship between bird abundance and wind turbine number; only a weak, but statistically significant, relationship with power output was observed, with lower power-rated turbines resulting in greater declines in bird abundance than higher-rated turbines. This study also found that bird abundance was significantly affected by the life-span of the wind energy development operation, with those that had been operational for longer time periods having higher effects on abundance.

Spatial avoidance can operate at the individual bird level, where an individual foraging or nesting bird locates itself further from the wind energy development and, subsequently, at a localised population level *i.e.* reduction in abundance and/or density (Pearce-Higgins *et al.*, 2009a; Marques *et al.* 2014). Displacement may have associated indirect 'cascade' responses (Schmidt and Ostfeld, 2003; Salo *et al.*, 2010), whereby some species are affected and that, in turn, affects other species. For example, wind energy development-mediated changes in prey species density or abundance may affect foraging predators, such as raptors (Pearce-Higgins *et al.*, 2009a; Wilson *et al.*, 2015). That is, habitat quality may be compromised to such an extent that indirect changes result in the avoidance of those habitats because of a reduction in their suitability and/or profitability for the species in question.

It has been suggested that displacement may affect breeding success in raptors (Bright *et al.*, 2008a; Carrete *et al.*, 2009) and displacement from suitable habitat has been suggested as causing a decline in the breeding success of two large raptors, White-Tailed Eagles and Griffon Vultures (Dahl *et al.,* 2012), although several studies show no detectable effects (see review in Wilson *et al.*, 2015). There is mixed evidence of habituation, with some reviews (Stewart *et al.*, 2005, 2007) suggesting that effects will persist throughout the operational period. Others suggest that this may vary between species (Marques *et al.*, 2014), but few studies have demonstrated this empirically (see Madsen and Boertmann, 2008).

Several studies attribute much of the perturbation caused by wind energy developments to the construction phase (Garvin *et al.*, 2011; Pearce-Higgins *et al.*, 2012; Campedelli *et al.*, 2013; Hull *et al.*, 2013; Stevens *et al.*, 2013) and associated disturbance and displacement effects. However, for some species (particularly seabirds, waders and raptors), long-term population effects have been shown to be more likely (Bevanger *et al.*, 2010; Nygard *et al.*, 2010; Dahl *et al.*, 2012). Conversely, some studies show that there are no detectable population level impacts (Devereaux *et al.*, 2008; Pearce-Higgins *et al.*, 2009a; Fielding and Haworth, 2010; Haworth and Fielding, 2012; Douglas *et al.*, 2011), particularly during the operational phase, although some species may be vulnerable to longer-term effects than others (Pearce-Higgins *et al.*, 2012).

The WINDHARRIER project reviewed wind energy interactions with Hen Harriers, as well as carrying out a series of Hen Harrier/wind energy development research packages in Ireland (Wilson *et al.*, 2015). It examined:

- population trends in relation to wind energy developments;
- the effects of wind energy developments on breeding bird communities;
- interactions with Hen Harrier breeding parameters;
- Hen Harrier flight behaviour in relation to wind energy development;
- Hen Harrier foraging behaviour; as well as
- wind energy development assessment guidance and recommendations for mitigation.

In its review of bird communities in and around wind energy developments, it was found that:

(i) bird densities were lower within 100m of wind turbines compared to control areas, particularly forest bird species;
(ii) differences in bird densities (within 100m) were related to habitat changes caused by wind energy development construction;
(iii) the extent of differences in bird densities depends on the extent of areas affected by changes in habitat during wind energy development construction;
(iv) the species of birds affected by these differences depends on which habitats are modified during wind energy development construction; and
(v) open-country bird species' densities were lower at wind energy development sites.

These may be due to large-scale effects of wind energy developments, landscape differences in habitats, or differences in management practices, but further research is required to determine the cause of these patterns.

The infrastructure associated with wind energy developments may also have additive effects. In particular, the requirement for both access (*i.e.* roads) and a distribution network (*i.e.* overhead power lines, if used) may cause other effects for birds (Drewitt and Langston, 2008; Martin and Shaw, 2010). Wind energy developments may also facilitate recreational access to previously inaccessible areas (Andrews, 1990; Trombulak and Frissel, 2000) via wind energy development roads and tracks, for vehicles such as scramblers or motorbikes, or for other activities such as turf extraction (see Ruddock *et al*., 2016a).

Displacement may occur where birds avoid areas around wind energy developments; they may also be affected by habitat modifications that consequently decrease their abundance in the area. Stewart *et al.*, (2005) and Whitfield and Madders (2006) indicated that nesting Hen Harriers are one of the least affected bird species with respect to displacement, and have one of the highest rates of avoidance in raptors (Garvin *et al.*, 2011). That is, this species will avoid wind turbines generally and they are considered to be less vulnerable to displacement. Madders and Whitfield (2006) reviewed several studies and found little evidence of large-scale displacement, ultimately suggesting that foraging avoidance mostly extended to approximately 100m, while nest displacement was reported at 200m to 300m. Bright *et al.* (2008a) and McGuinness *et al.* (2015) both considered in their respective sensitivity models that Hen Harriers were sensitive to wind energy developments at 2km.

Displacement of Hen Harrier can occur through displacement from nesting or roosting locations, and/or displacement from foraging areas. The key field study that examined displacement in Hen Harriers (Pearce-Higgins *et al.*, 2009a) found that avoidance extended to 250m from turbines, with reduced flight activity, and that breeding density would be consequently reduced by 52.5% (range -1.2% to 74.2%). This study also found that risk exposure of Hen Harriers was unrelated to flying height and that there was no significant reduction in abundance from wind energy development tracks or transmission lines. Pearce-Higgins *et al.* (2009a) have recognised that the avoidance rates recorded in their study may be highly site-specific. Haworth and Fielding (2012) concluded from a review of UK wind energy developments that harriers are displaced at relatively small scales of between 0-100/200m.

In Scotland, nests have been recorded at one site, Cruach Mhor, where there was an inclusive habitat 'enhancement area', between 131m and 476m (average = 284m) from turbines (SPR, 2009; Robson, 2011). Elsewhere in Scotland, nests have been recorded 110m from turbines, where disturbance exclusion zones were used (Forrest *et al.*, 2011, as cited in *Wilson et al*., 2015), with a similar density of nesting pairs recorded in pre- and post-construction (2.6 pairs pre-construction phase; 2.4 pairs operational phase; with 4.5 pairs construction phase) (Forrest *et al.*, 2011, as cited in AEC, 2012). Both of these sites also recorded Hen Harriers nesting within a few hundred metres during construction phases. McMillan (2014) reports that, whilst breeding activity was recorded close to turbines in the year of construction (following cessation of construction in March), a nest was located at around 800m away from the wind energy development, although it is not clear if this refers to the same breeding pair (*i.e.* which would indicate displacement). This same study reports nesting Hen Harriers 500m from turbines and less than 200m from access tracks. During wind energy development construction, displacement has been suggested to potentially occur for up to 500m around construction sites, with some disruption up to 1km, depending on the line of visibility (Madders, 2004; Bright *et al.* 2006).

These studies show that individual responses vary (see review in Wilson *et al.*, 2015) but typically extend from 50m to 800m. Several reviews have recommendations for set-back distances. For instance, in their reviews of Hen Harrier disturbance zones, Currie and Elliot (1997), Petty (1998) and Ruddock and Whitfield (2007) suggested buffers of 500–600m, 500–1000m and 500–750m respectively. Such metrics are frequently applied to wind energy development developments (Obermeyer *et al.*, 2011).

Johnson *et al.* (2000) recorded relatively high abundance of Northern Harrier utilising a Before-After-Control-Impact (BACI) study and found that there was a decline in abundance in the first year after construction but that this displacement was different between years. This study also found that avoidance was small-scale, less than 100m from turbines, and may have been related to the associated habitat changes (Madders and Whitfield, 2006; Whitfield and Madders, 2006). Garvin *et al.*, (2011) found from observations of abundance that, for Northern Harriers, there was a temporal lag in observed displacement (*i.e.* later in the operational phase) with 100% avoidance observed, which extended to around 100m from turbines.

Studies in Ireland show that Hen Harriers may relocate their breeding sites at increasing distances from turbines following construction, *e.g.* a 200–300m average increase in distance away from turbines was observed at a site that had been a Hen Harrier territory for more than 20 years (O'Donoghue *et al.*, 2011). That study observed total displacement during the year of construction; after construction, average set-back distance of nests was 501m (range 140m – 760m) from nearest turbines. O'Donoghue *et al.* (2011) also noted that the breeding Hen Harrier territories examined had significantly different breeding success, with 79.2% breeding success in areas where there were no proposed wind energy developments, compared to 16.7% in areas with energy development proposals - this was not directly linked to extant wind energy development sites but may be indicative of (unconfirmed) persecution or accidental disturbance during the early/pre-construction phases of wind energy development.

In a study at Derrybrien (Co. Galway), Madden and Porter (2007) compared pre- and post-construction survey results and found that one pair of Hen Harriers was recorded nesting within 1km of the wind energy development in the two years after construction, although most pairs were located between 1km and 5km away (9 – 10 pairs). The study also showed that Hen Harriers continued foraging near operational turbines and were recorded between 10m and 100m away from turbine bases. They concluded that absolute or total displacement was not evident, at least in the short-term, post-construction.

In certain circumstances, noise disturbance can originate from wind turbines, including mechanical noise derived from turbine components such as the gearbox and generator in the nacelle, as well as aerodynamic noise caused by the rotation of turbine blades. There are few studies of wind energy developments and the impacts of noise (see Ruddock and Reid, 2010). However, since Hen Harriers hunt largely by auditory means (Simmons, 2000), it is conceivable that foraging efficiency and prey detection may be compromised when they are in close proximity to turbines (see Wilson *et al.*, 2015). The width of the zone of influence may vary, depending on how far the noise travels. Noise modelling, which takes the turbine model into account, can be carried out to inform the scale and extent of increases to noise that can be anticipated around operational turbines.

Another study, Madders (2004), (cited in Wilson *et al.*, 2015), reports that some disruption may occur up to 1km from a construction disturbance, along the Hen Harrier's line of sight.

Volunteer surveyors conducted field observations as part of the 2010 National Hen Harrier Survey; subsequently, Ruddock *et al.*, 2012 reported wind energy development-related disturbance as the suspected reason for Hen Harrier breeding failure at five separate locations in Co. Cavan, Co. Kerry, Co. Cork and Co. Limerick. In the 2015 survey (Ruddock *et al*., 2016a), disturbance was examined in greater detail; at the national level, reports of wind energy developments as pressures were relatively infrequently recorded (*i.e.* the 11th most frequently recorded pressure within 500m and 2km of Hen Harrier territories). However, it was the 4th most frequently recorded pressure within four of the six SPAs.

Fieldworkers did not record any wind energy development pressures in the Slieve Blooms or Slieve Beagh SPAs in the most recent (2015) national survey but Ruddock *et al.* (2016) outlined that wind energy developments may have been a causal factor in recent declines in Mullaghanish to Musheramore Mountains SPA and also in West Limerick. Ruddock *et al*. (2016a) recommended that further spatial analyses of wind energy developments and Hen Harriers within the Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPA complex and the Slieve Aughty Mountains SPA be undertaken, as these sites have a relatively large number of turbines within the SPAs (see Chapter 3).

Comparing data from 36 of the 10km squares with breeding pairs during the 2000 survey revealed a marginally non-significant negative relationship between wind energy development presence and changes in the number of breeding pairs between 2000 and 2010 (Wilson *et al*., 2016). There was a 28% spatial overlap of the 69 10km squares which held breeding Hen Harriers in the 2010 national survey and the presence of wind energy developments (Ruddock *et al.*, 2012). In areas between 200m and 400m asl, a considerable overlap exists (28% in the 69 10km squares which held breeding pairs in 2010) between Han Harrier breeding distribution and the location of wind energy developments in Ireland (Wilson *et al.*, 2016). This relationship was found to be only weakly significant and linked to the interaction between wind energy developments, Hen Harriers and altitude (200 – 400m) but interactions with other factors (*e.g.* habitat, disturbance, persecution) could not be excluded.

In relation to Hen Harrier breeding parameters, Wilson *et al.* (2015) and Fernández-Bellon *et al.* (2015) conducted a field study as part of the WINDHARRIER project. The field study examined the proximity of turbines in relation to breeding parameters of Irish Hen Harriers, including metrics for:

(i) nest success (the proportion of nests that fledged one or more young);
(ii) fledged brood size (*i.e.* the average number of fledged chicks per successful nest); and
(iii) over-all productivity of breeding pairs (*i.e.* the average number of fledged chicks across all nesting attempts).

There were no statistically significant relationships found between these breeding parameters and nest distance from the nearest wind turbine. However, observed lower nest success within 1 km of wind turbines, compared to the success of all nests more than 1km from wind turbines, was close to statistical significance, *i.e.*

- breeding success was statistically non-significantly lower within 1000m of wind turbines, although sample sizes were relatively small; and
- based on composite considerations of findings, it is possible that lower breeding success recorded within 1000m of wind turbines reflects a biologically relevant pattern.

These findings concur with similar maximum direct disturbance or indirect displacement distances recorded in other field studies (Ruddock and Whitfield 2007; Pearce-Higgins *et al.*, 2009a).

Cumulative Effects and mitigation

As outlined above, during the various phases of wind energy development, risks may arise to Hen Harrier for a variety of reasons. In addition to individual or population-level effects, there may also be cumulative effects, with the effects arising from any one wind energy developments combining with those arising from others to create a much more significant effect. There have been numerous concerns raised about this in the scientific literature, but few studies have found explicit results or negative associations (Fielding *et al.*, 2006; Telleria, 2009a).

Effects of wind energy developments on Hen Harriers

The impacts described above could affect both Hen Harrier breeding (nesting and foraging) or wintering (roosting and foraging) habitats. The severity of such impacts may be more pronounced during the breeding season (O'Donoghue *et al.*, 2011), particularly when there are dependent young in a nest, compared with during the non-breeding/winter season, when individual birds can move away from adverse impacts that arise. Depending on the scale and direction of impacts, if any, there may be wider cumulative or population-level effects arising.

It is a conceivable risk that wind energy development mortality and/or displacement is additive to existing habitat displacement (*e.g.* via forestry related habitat constraints or recreational disturbance) and other mortality factors (*e.g.* illegal killing or disease). The Hen Harrier has also been noted to be at risk of collision mortality during migratory (passage) movements at offshore wind energy developments (Wright *et al.*, 2012; see Katzner *et al.*, 2016).

Impacts on Hen Harrier Ecology from Wind Energy Development

The impacts as they relate to various aspects of Hen Harrier ecology are set out below.

Potential impacts on foraging habitat and behaviour

As noted previously, generally, foraging Hen Harriers prefer open habitats. In particular, heath/bog, low intensively farmed grassland and semi-natural open habitats with well-established hedgerows, pre-thicket forest and areas of scrub are the main habitats used by foraging harriers (Irwin *et al.*, 2012; O'Donoghue, 2012). Therefore, loss, change, degradation or fragmentation of these types of habitats as a result of wind energy developments, particularly the preferred habitats, could affect foraging Hen Harriers through direct loss or changes to habitats.

- Wilson *et al.* (2015) completed a strategic vantage point study of Hen Harrier habitat usage at wind energy developments and control sites. This found that Hen Harriers foraged preferentially over peatland and pre-thicket habitats, while avoiding closed canopy and natural and semi-natural open habitats. At wind energy development sites, Hen Harriers preferentially foraged in peatland and also avoided closed canopy forest. Hen Harriers at wind energy developments did not use thicket areas for hunting, but preferentially used areas of natural and semi-natural open habitats. The study highlights the importance of open habitats (rough grassland, natural grasslands, scrub and peatland) for foraging Hen Harriers in Ireland.
- Further GPS tracking of a single female (Wilson *et al.*, 2015) found that habitat selection in relation to wind energy developments indicates that natural and semi-natural open habitats, peatland and clear fell were flown over more frequently than expected, and improved grassland was used less frequently than expected.

Direct foraging habitat losses could result from the footprint of development but also if wider habitat alteration is undertaken (Wilson *et al.*, 2015; SNH, 2016). Further to this, indirect effects could occur whereby prey species are affected (*e.g.* reduced density of prey species near wind energy developments (Pearce-Higgins *et al.*, 2009a; Wilson *et al.*, 2015; Fernández-Bellon *et al.*, 2019)) or during key periods of activity, such as construction (Pearce-Higgins *et al.*, 2012), which may have consequential effects on harrier foraging efficiency and subsequent breeding success and/or productivity. However, contrary to potential negative impacts, the reduced suitability of wind energy development areas may lead to avoidance and therefore, a reduced collision risk (SNH, 2016).

Previous research has indicated that avoidance of wind energy developments by breeding Hen Harriers may occur within 1km of turbines (Pearce-Higgins *et al.*, 2009a) and that foraging behaviour of breeding pairs can be influenced by habitat changes at distances up to 3km from the nest (Amar *et al.*, 2004, Arroyo *et al.*, 2009). Based on an analysis of foraging spatial data derived from the remote tracking of three individuals from one study site (the Ballyhouras), Irwin *et al.* (2012) noted that the maximum distance travelled from the nest was 7.5km (female) and 11.4km (male). These are significantly further than the estimates for Scottish breeding birds (2.5km (female) and 9km (male)) (Arroyo *et al.*, 2009; Arroyo *et al.*, 2014). This may be because Irish Hen Harriers breeding in forested landscapes have to forage over larger areas in order to provision broods (at least, in the Ballyhouras) or it may be a reflection of the relatively lower potential prey availability in Ireland (O'Donoghue, 2010; Ruddock *et al.*, 2012; Wilson *et al.*, 2015). These larger potential foraging ranges of Hen Harriers in Ireland mean that the potential for wind energy development-induced habitat management or changes may impact Hen Harriers at a relatively greater range (distance) than is predicted elsewhere.

Potential impacts at the nest site

A disturbance event that causes the incubating female to flee the nest or that deters the return of provisioning parents can expose eggs and chicks to cold, rain or lack of food (Hamerstrom, 1969; Scharf and Balfour, 1971; Picozzi, 1980). Mammalian predators may be attracted to nests by visual cues such as the presence of humans, trampling of vegetation, increasing activity of parent birds in response to disturbance events, as well as by olfactory cues (Whelan *et al.*, 1994; Skagen *et al.*, 1999).

Potential impacts at winter roost sites

As already mentioned, birds frequent roost sites outside the breeding season (broadly defined as mid-August to mid-March), probably for shelter and protection (O'Donoghue, 2010). Roosts function as foci from which the Hen Harriers radiate out and forage in the local landscape (O'Donoghue, 2010). Currently, two SPAs are listed for non-breeding Hen Harrier and, based on the published data available, the majority of the known wintering roost sites occur outside of the SPA Network (Figure 3).

The main threats and pressures on Hen Harriers at winter roost sites have been identified to be predominantly agricultural reclamation (roost loss and associated habitat loss); timing of cultivation practices such as ploughing and spraying (reduction in prey availability and disturbance); renewable wind energy development (displacement and direct disturbance); and human disturbance (NPWS, 2013). Forestry-related activities may potentially cause disturbance events at a small number of known roosts (NPWS, 2015a).

Where there is a requirement to avoid disturbance to breeding birds, the construction activity is more likely to be undertaken during the wintering season. This temporal consideration may thus have a greater potential impact on winter roosts rather than nests. In those breeding sites, and indeed outside of breeding sites, where suitable winter roost habitats also occur, it is important that impacts are mitigated to also avoid disturbance and prevent loss of winter roost sites.

Potential impacts on winter foraging habitat

Wilson *et al.* (2015) focused on the breeding season and there are no documented studies of Hen Harrier foraging behaviour in the non-breeding seasons. It is conceivable that, where wind turbines occur in foraging habitats used by Hen Harriers during the non-breeding period, these may influence their use by the bird. Similarly, loss or changes to habitats that hold abundant food supplies for prey species may affect Hen Harrier foraging efficiency, as has been noted for breeding season foraging habitats. That is, since passerine bird species, particularly thrush species, have been identified to be a frequently-recorded prey-item in the winter diet of Hen Harriers (see O'Donoghue, 2004; 2010), habitats with high abundance of such prey species will be a valuable resource to the birds and they may be impacted by any associated changes.

O'Donoghue (2010), however, found that Hen Harrier diet varied geographically, with more wading birds and small mammals recorded in the diet of birds associated with the lowlands of southern and eastern areas; therefore, diet could be affected in the wider countryside in different ways. There is little detailed information available on the types of habitats utilised by Hen Harriers for foraging over the winter season, but the species is generally more widespread then and thus, may be vulnerable to disturbance over a wider area during the winter. This vulnerability may be increased if construction takes place during the winter, but also in the long-term, they may be vulnerable to indirect displacement due to their avoidance of wind energy development sites in the wider countryside.

Mitigating the Effects from Wind Energy Developments

Mitigation measures to reduce direct mortality to birds from wind energy developments have included various methods including:
- temporal cessation of turbines during high risk periods (de Lucas *et al.*, 2012; Smallwood, 2013; European Commission, 2020b),
- removal of specific turbines (Martinez Abrain *et al.*, 2013; Smallwood, 2013),
- changing turbine design and spacing (European Commission, 2020b) and
- repowering to reduce overall number of turbines and risk (Smallwood, 2013; Warren and Birnie, 2009).

Mitigation to reduce the effects of disturbance to bird species have been suggested, though with varying levels of supporting evidence. They include:
- restricting construction during the breeding season (Pearce-Higgins *et al.*, 2012; European Commission, 2020b),
- erection of physical screens during the construction phase (Pearce-Higgins *et al.*, 2012);
- use of alternative construction methods (European Commission, 2020b).

The creation of habitat to offset Hen Harrier habitat loss has been determined not to be mitigation (in the meaning of a Habitats Directive Article 6(3) assessment), but is rather a measure to be assessed pursuant to Article 6(4) (*i.e.* compensation) (Supreme Court, 2016; ECJ, 2018).

There are a number of identified research priorities (Wang and Wang, 2015) that, if fulfilled, would enable a better understanding of the sector and its interactions with birds, in light of developing technologies, equipment and particularly, with regard to repowering operations in the future (Hotker, 2006; Smallwood and Karas, 2008; Warren and Birnie, 2009; SNH, 2014; Northrup and Wittemayer, 2016).

CHAPTER 3: POTENTIAL POPULATION LEVEL IMPACTS OF WIND ENERGY-RELATED ACTIVITIES ON THE HEN HARRIER IN IRELAND

Introduction

This chapter builds on the description of the overlaps and potential interactions between wind energy developments, their associated management and the ecology of Hen Harrier. This examination of the potential population level impacts on Hen Harrier by the wind energy sector in Ireland is framed by first quantifying the spatial and temporal extent of these interactions.

This review obtained a database from SEAI of individual turbines from 1992 to (June) 2016 for analysis. SEAI have been systematically obtaining details of individual wind turbines (>100kW) from planning files and ortho-photography sources across Ireland for a number of years (J. McCann, pers. comm.). The database captures information on individual turbines and includes site name, spatial co-ordinates (easting/northing), power output (MW), hub height (m), rotor diameter (m), county and connection reference number.

As part of this review, the SEAI database was standardised, and spatially checked and verified against ortho-photographs. The connection year and month were derived from separate publicly available databases (Eirgrid's TSO & ESB respectively) using the unique connection reference numbers. A number of spatial anomalies were rectified and a number of additional turbines were digitised from the ortho-photographs. Altitudes (metres above sea level) were calculated for each individual turbine from a digital elevation model (ASTER) of Ireland. This resource is now known and referred to as the Review Turbine Database 2016 or RTD (NPWS, unpublished) throughout this report.

Potential interactions of wind energy and Irish Hen Harrier breeding populations

As previously discussed, where there is a contiguous spatial overlap between wind energy developments and Hen Harrier breeding habitats, there may be both a direct loss of habitat (Madders and Whitfield, 2006) and a displacement effect (Pearce-Higgins *et al.*, 2009a; Pearce-Higgins *et al*., 2012) which may occur spatially at the small (wind energy development) scale and within a wider associated zone of influence (Madders and Whitfield, 2006; Pearce-Higgins *et al.*, 2009a; O'Donoghue *et al.*, 2011; Fernández-Bellon *et al.*, 2015; Wilson *et al.*, 2015).

Similarly, Hen Harriers are known to be affected by direct collision mortality (Lekuona and Ursúa, 2007; Scott and McHaffie, 2008; RSPB, 2012; this study). All of these impacts may have consequences for individual birds but they also, depending on the number of collisions, may have wider population level effects. It is conceivable too that the occurrence of wind turbines may affect breeding parameters such as:

- abundance (Usgaard *et al*., 1997; Pearce-Higgins *et al.*, 2009a);
- density close to turbines <500m (Pearce-Higgins *et al.*, 2009a);
- breeding success (Fernández-Bellon, 2015);
- brood sizes; and/or
- productivity (O'Donoghue *et al.*, 2011; Hatchet *et al.*, 2013; Bennett *et al.*, 2014); and
- mortality (Carrete *et al.*, 2009).

Co-occurrence of wind turbines and breeding Hen Harriers

Wilson *et al.* (2015; 2016) quantified the spatial overlap with wind energy developments (up to and including 2012) at 10km resolution, using WEI data on wind energy developments, and Hen Harrier data from the 2000 and 2010 breeding surveys (Norriss *et al.*, 2002 and Ruddock *et al.*, 2012 respectively). This study found that there was a 28% overlap (n = 19 of 69 squares) at the 10km resolution, based on 2010 breeding data (Ruddock *et al.*, 2012); there are similar metrics recorded for elevation data of breeding Hen Harriers and wind energy developments, with the majority of wind turbines (67%) and Hen Harriers (62%) occurring at 200m to 400m asl.

These studies indicated that there was a weak negative relationship between wind energy development presence and Hen Harrier breeding populations between 2000 and 2010, with an approximate average loss of one pair in squares with turbines, compared to squares without turbines. This was more strongly observed at 200m to 400m elevations. There were no observed relationships in that study between the number of turbines built and population changes (Wilson *et al.*, 2015). The WINDHARRIER study also indicated that other factors (*e.g.* forest habitat changes) may also be interacting with the observed pattern of Hen Harrier declines and that further research was required.

Wilson *et al.* (2015; 2016) analysed data at a 10km resolution, including for altitudinal data and interpretation of ortho-photography for analysis of change between surveys. The RTD (NPWS, unpublished) now enables a more fine-scale resolution for this review so that spatial interactions with Hen Harriers and wind turbines can be further examined.

As explained earlier in the report, the analysis reported on here was undertaken in 2017, based on available wind turbine data (up to June 2016). The timing of this analysis was designed to allow contemporaneous analysis with the results of the 2015 National Hen Harrier Survey (Ruddock *et al.*, 2016). Due to the Covid-19 pandemic, the anticipated 2020 National Hen Harrier Survey was not undertaken and so, turbine data presented here has not been updated, as there is no corresponding update of Hen Harrier data. As of 2016, there were 1,502 turbines recorded in the database as having been connected since 1992 (*i.e.* 1992-2016) (Figure 6). Those turbines connected in 2016 (n = 25) were not excluded since these were commissioned in 2015 and were considered to have been present at the time of the 2015 Hen Harrier survey. Turbines in the database (*i.e.* from that time period 1992-2016) range in size from 0.05MW to 3MW, with the majority of turbines in Ireland being 0.85MW (22.1%) and 2.3MW (15.3%) machines. Hub heights ranged from 25m to 100m and blade diameters from 15m to 117m (NPWS, unpublished). Generally, the lower rotor-swept areas ranged from 19 to 50m above ground level (with a small number of "outlier" turbines with a lower rotor-swept height of just 10m), whilst the rotor swept heights ranged from 25 to 156m above ground level (NPWS, unpublished). More recent information is available from IWEA's online data viewer.

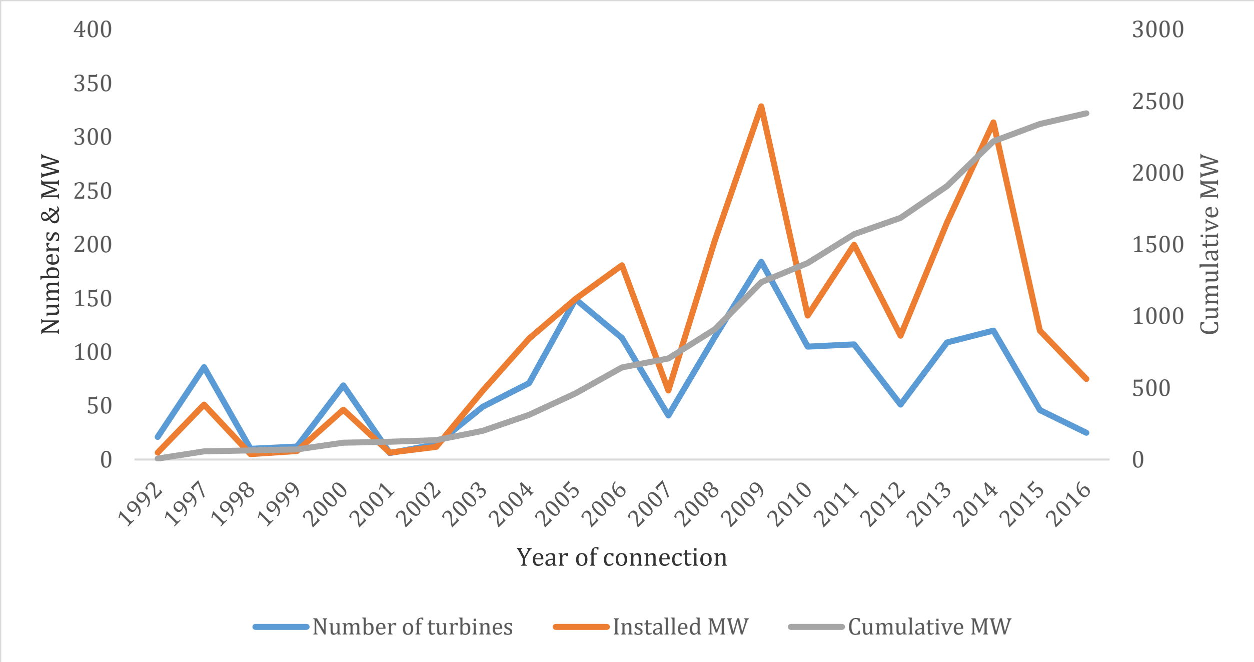

Figure 6. Numbers of turbines installed and power output 1992 - 2016

These 1,502 turbines were recorded in 120 10km squares across Ireland, which equates to 13.8% of the 869 10km squares that cover the national land territory. Between one and 75 turbines have been installed per 10km square, ranging in cumulative power from 0.16MW to 111.8MW per 10km square. Turbines in Ireland were recorded at altitudes ranging from 2.9m asl and 510m asl (average 253m ± 108.7m). Turbines were most frequently located in the 300 – 350m and 200 – 250m ranges (Figure 7).

Confirmed 2010 breeding Hen Harriers territories (see Ruddock *et al.*, 2016a for definitions) were located between 71m and 452m asl (average 243.8m ± 88.5m) and were most frequently located between 150m and 300m *i.e.* 22% were located between 150 and 200m, 19% between 200 and 250m, and 20% between 250 and 300m (Figure 7). 81.9% of turbines were located in the 100 – 400m range whilst 92.6% Hen Harriers were located in the same range. 66.7% of turbines and 59.3% of Hen Harriers occurred between 200 – 400m. Earlier survey data (Table 1) found a similar range of altitudes for confirmed pairs during 1998-2004 (range 72 – 495m, average 257.1m); 2005 (range 87 – 401m, average 227.9m) and 2010 (61 – 423m, average 239.6m).

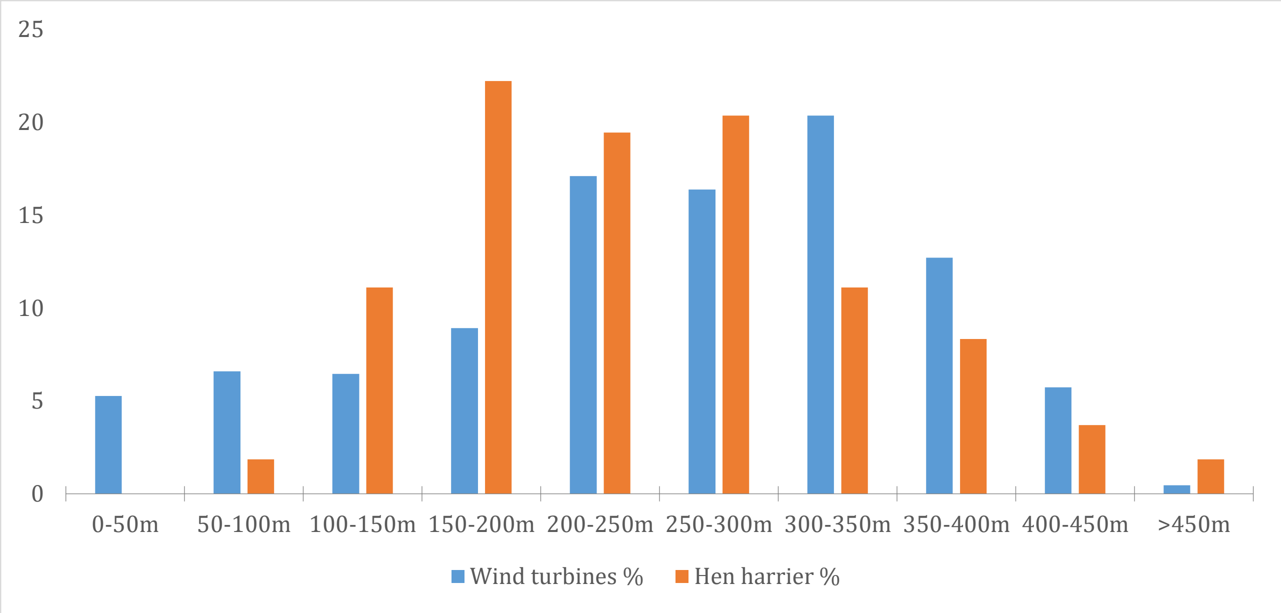

Figure 7. The elevation (m asl) of both wind turbines and % (y axis) of confirmed breeding Hen Harriers territories in Ireland, 2015.

From the 2015 Hen Harrier survey data, turbines were recorded in 21.6% of the 10km squares surveyed (n = 58 of 269 squares); and turbines were present in 32.5% (n = 27) of the 10km squares with either confirmed or possible breeding territories (n = 83) (Figure 8). Most turbines (n = 420) were recorded in the 10km squares that had *confirmed* breeding Hen Harriers (Table 1 and Figure 9).

Table 1. Hen Harrier 10km survey squares in 2015 and their spatial overlap with wind turbines.

Details from 2015 survey (Ruddock *et al.* 2016a)	Confirmed breeding	Possible breeding	Seen	Not seen/Vacant
Number of survey squares	61	22	55	130
Number of squares with turbines	22	5	13	18
Percentage of squares with turbines	36.1	22.7	23.6	13.8
Total number of turbines	420	100	150	196

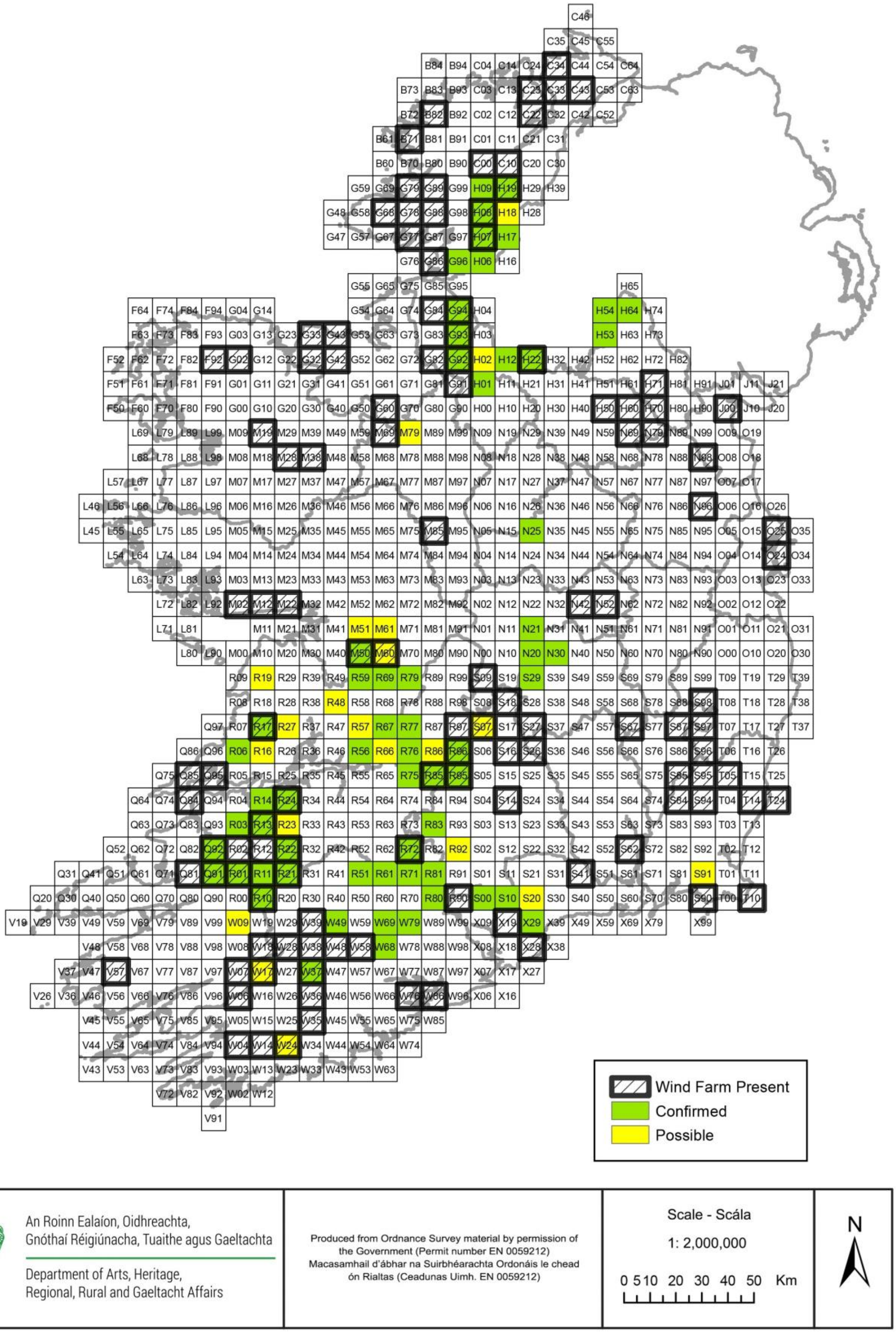

Figure 8. The distribution of wind turbines from 1992 – 2016 and Hen Harrier confirmed and possible breeding 10km distribution in 2015 (Ruddock *et al.*, 2016a).

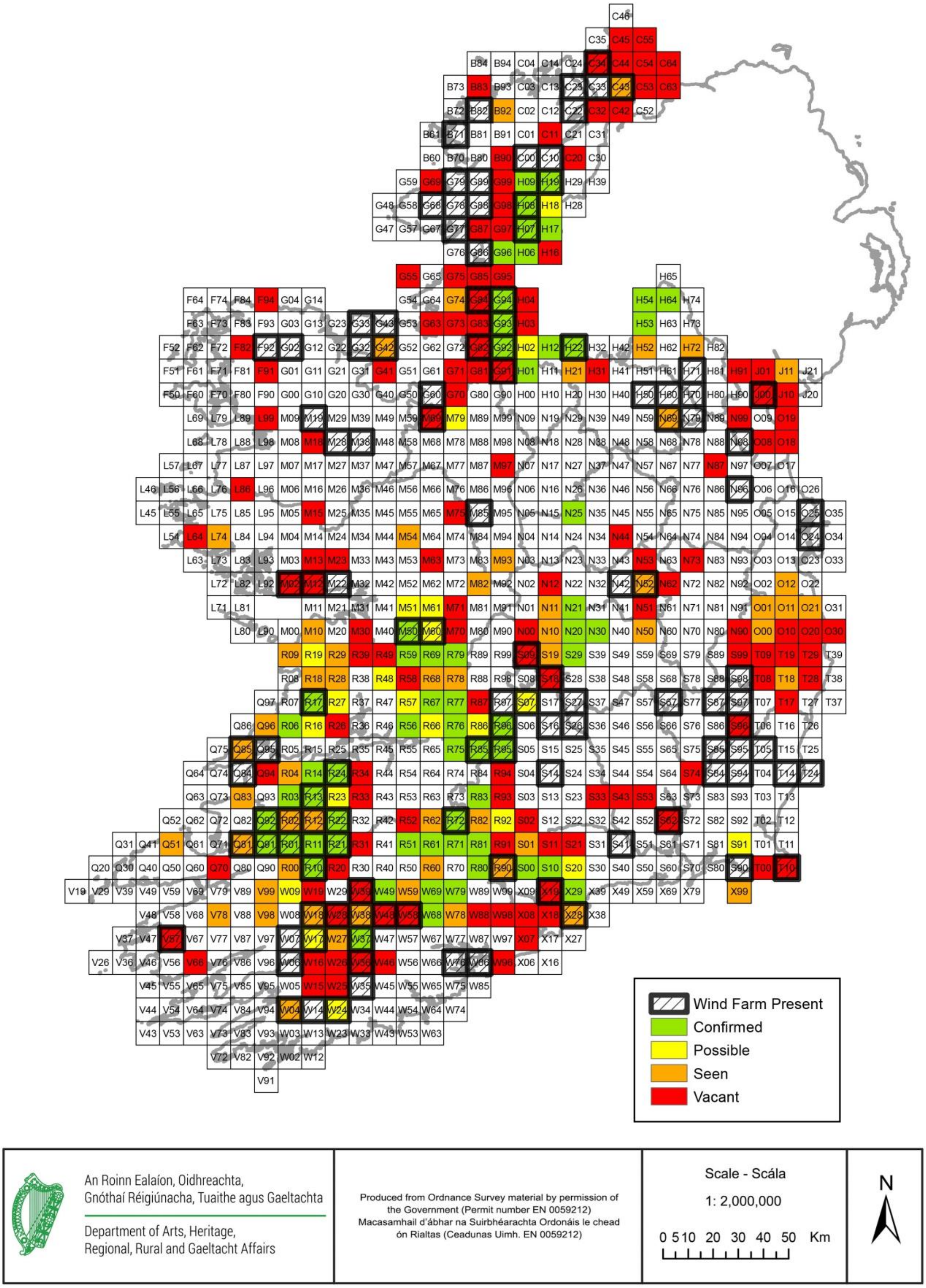

Figure 9. The distribution of wind turbines from 1992 – 2016 and Hen Harrier Confirmed, Possible, Seen and Vacant 10km breeding distribution in 2015 (Ruddock *et al.*, 2016a).

Since the first national survey, the proportion of spatial overlap with wind energy development has increased, particularly within the confirmed Hen Harrier breeding range (Table 2).

Table 2. The results of breeding 10km survey squares in 1998-2000, 2005 & 2010 and spatial overlap with wind turbines.

	1998 - 2000		2005		2010	
Details from national survey	Confirmed	Possible	Confirmed	Possible	Confirmed	Possible
Number of squares	42	17	60	6	62	7
Number of squares with turbines	3	1	11	2	18	0
Percentage of squares with turbines	7.1	5.9	18.3	33.3	29.0	0
Total number of turbines	54	10	168	29	313	0

Displacement of Hen Harriers and wind energy in Ireland

Using details of all turbines (up to and including 2016) and historical Hen Harrier databases (1998 – 2004; 2005; 2010 and 2015), there is a decreasing number of confirmed and possible Hen Harrier territories located within 500m and 1km of turbines over time (Figures 10 and 11). This may be suggestive of some small-scale avoidance by Hen Harriers close to turbines (up to 500m as described in Pearce-Higgins *et al.*, 2009a; up to 1km from turbines as described in Fernández-Bellon *et al.*, 2015). As detailed earlier in Chapter 2, this may be an artefact of the decreasing Hen Harrier population as well as being compounded by other factors not examined in this desk-review *e.g.* habitat composition or changes (see Wilson *et al.*, 2015; 2016). However, it may also indicate genuine avoidance behaviour of Hen Harriers with respect to wind turbines in Ireland (as in other harrier species – see Schaub *et al.,* 2020) and warrants further statistical examination, alongside other potential compounding factors.

This analysis of turbine distances also indicates that turbines have been built within 1km of at least 50 historically confirmed or possible breeding territories since 1998. Over time, the distance from turbines to confirmed breeding sites has decreased (Figure 12; Table 3). The average distances in 2015 were 10.7km to 9.3km for confirmed and possible pairs respectively (Table 3) which may concur with the possible displacement of 5km to 10km (Figure 10 and 11). Whilst some pairs of Hen Harriers will nest close to turbines (see minimum distances in Table 3), these locations almost exclusively occur within the Stack's SPA which has a relatively high number of turbines.

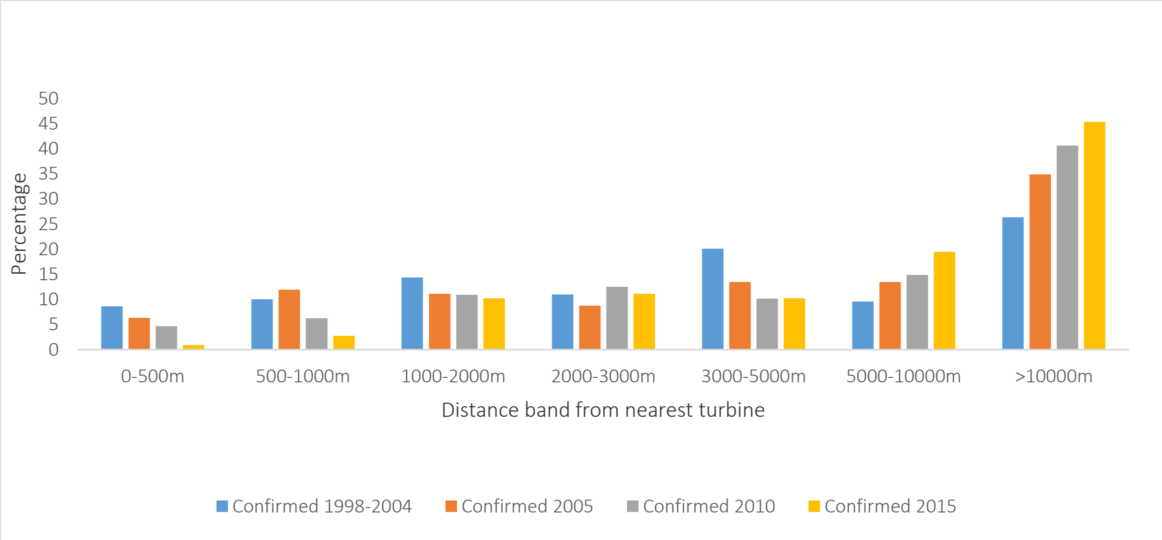

Figure 10. The percentage of confirmed breeding Hen Harrier territories occurring per distance band from nearest turbine (from national surveys 1998-2004, 2005, 2010 and 2015).

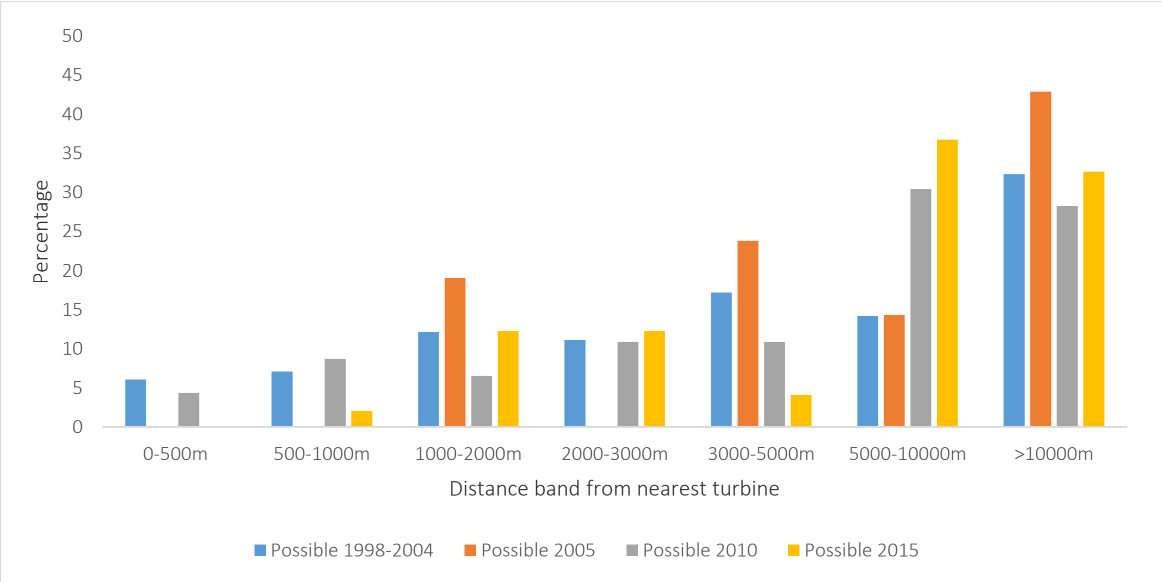

Figure 11. The percentage of possible breeding Hen Harrier nests occurring per distance band from nearest turbine (from national surveys 1998-2004, 2005, 2010 and 2015).

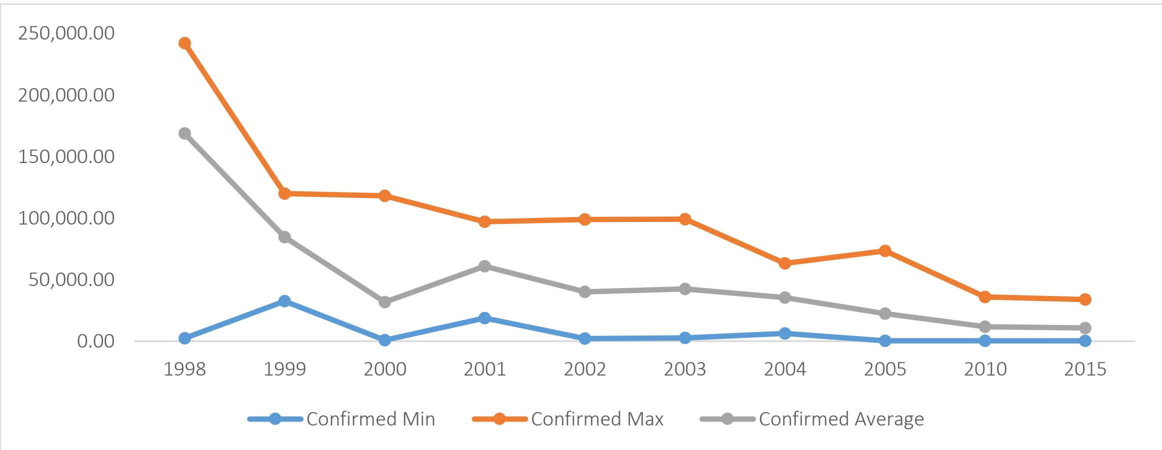

Figure 12. Turbine distance (m; y-axis) from confirmed breeding Hen Harrier territories in national survey years 1998 – 2015.

Table 3. Turbine distances from locations of breeding Hen Harriers in national survey years, based on all turbine data, up to and including 2015.

	Year	1998	1999	2000	2001	2002	2003	2004	2005	2010	2015
	Confirmed	39	48	26	11	31	29	25	132	128	108
	Possible	16	17	12	6	13	24	11	21	46	49
	Total	55	65	38	17	44	53	36	153	174	157
Confirmed	**Min**	2,400.4	32447.6	770.9	18,744.1	1,972.4	2628.8	6128.8	252.4	300.6	231.0
	Max	241,924.6	119,825.2	117,910.6	97,073.0	98,734.8	98,997.3	63,057.6	73,400.9	35,897.3	33,786.9
	Average	168,557.9	84,427.8	31,746.7	60,782.4	39,954.7	42,365.5	35,391.1	22,308.7	11,705.2	10,714.0
	<1km	0	0	3	0	0	0	0	17	41	16
	1-2km	0	0	33	0	1	0	0	98	195	90
	2-3km	8	0	62	0	16	16	0	202	426	257
	3-5km	25	0	100	0	25	36	0	654	943	732
	>5km	25	0	203	0	63	116	1	1781	2025	2116
	Altitude min	22	22	97	34	123	76	161	87	61	71.2
	Altitude max	495	495	361	432	418	422	388	401	423	452.4
	Altitude ave	274.3	275.1	242	232.2	249.5	221.4	272.7	238.8	239.6	243.8
Possible	**Min**	118,239.30	57,969.30	22,152.7	31,813.3	20,630.7	6,579.2	2,536.3	1,972.4	316.4	959.8
	Max	240,584.3	118,502.8	70,465.8	88,771.3	100,994.0	99,995.7	56,794.9	50,343.3	32,257.6	33,231.2
	Average	189,895.4	80,999.9	51,864.8	59,735.4	62,744.6	35,857.2	25,134.8	25,709.3	9,410.2	9,330.6
	<1km	0	0	0	0	0	0	0	0	6	1
	1-2km	0	0	0	0	0	0	0	1	39	43
	2-3km	0	0	0	0	0	0	1	16	65	141
	3-5km	0	0	0	0	0	0	2	66	205	358
	>5km	0	0	0	0	0	62	3	127	1129	1094
	Altitude min	229.2	99	35	133	76	13	185	69	49	67.5
	Altitude max	13	378	287	374	360	392	422	471	431	488.3
	Altitude ave	409	235	189	213	252.9	203	309.5	259.2	234.1	252.9

Pressure records in Hen Harrier breeding areas from wind energy in Ireland

Fieldworkers for the 2015 national survey were requested to record the threats or pressures observed, if any, within 500m and within 2km of the survey area in order to facilitate a strategic assessment of these metrics at the regional and national levels, using the EU's Birds Directive Article 12 pressures and threats (further details in Ruddock *et al*., 2016a). "Pressures" are current, while and "threats" are in the future, and include the collection of information on wind energy production (see European Environment Agency (2018) for more information on pressure codes) (Figure 13).

At the time of the survey, wind energy developments were present in 120 10km squares across Ireland, while wind energy development pressures were recorded in 33 10km squares, of which only 63.6% are noted to actually contain wind turbines (Figure 13). Therefore, it appears that fieldworkers were either aware of impending wind turbines, perhaps from wind energy road development, and/or that they considered the pressure arose from turbines they could observe within adjacent squares (and within 2lkm of the survey area as per the methodology), and reported accordingly. There were also power line (D3) pressures recorded at 26 squares, 57.7% (n = 15) of which also had wind energy development (C3) pressures recorded, and 38.5% (n = 10) of which had wind turbines present. This indicates that power lines occur more widely than wind energy developments, but also that they may not be located in and/or around existing wind turbines, as underground cables may be used by wind energy developments instead, and, in fact, the power lines may not be related to the wind energy development at all.

Breeding population changes and wind energy in Ireland

Ruddock *et al.* (2012; 2016a) suggested that wind turbines and associated mortality and displacement warranted further investigation. As noted above, Ruddock *et al*. (2016a) also reported that, in some areas, Hen Harriers were perceived by surveyors to be under pressure from wind energy developments. Based on data derived from the 2000 and 2010 national surveys, Wilson *et al.* (2015; 2016) found evidence that population decline may be associated with the presence of wind turbines. However, that study found that there were also interactions evident with both altitude and habitat changes and wind energy developments. The mechanism for this decline is not clearly defined and could relate to either direct or indirect disturbance sources that result in displacement of territorial birds during the breeding season. The relationship between wind turbines and Hen Harriers may therefore be a complex one, and minimization of spatial conflict in order to reduce the likelihood of effects would be desirable (see Chapter 4).

The number of turbines in those squares in which Hen Harrier declines (1 to 6 pairs) had been recorded between 2010 and 2015 increased by 131 (281 turbines to 412; 46.6%). Conversely, for squares where population increases were recorded (+1 to +3 pairs), turbines increased by 51 (109 to 160; 46.8%). This indicates that the proportional increase of turbines may not affect rates of population change, since both percentage increases in turbines were similar. Rather, the density of existing and installed turbines may be driving the change. However, it is recognised that other factors may also be interacting (such as forestry and agricultural activities) and they are not analysed further here (see NPWS reports on Hen Harrier and these sectors- NPWS, 2015a and 2015b).

Similarly, between 2005 and 2010, in those squares where Hen Harrier numbers declined (by 1 to 4 pairs), turbine numbers increased from 109 to 194 (70.2% increase), whereas for squares in which Hen Harriers increased (by 1 to 6 pairs), there was an increase of 56 to 119 turbines (112% increase). This further indicates that the rate of turbine increase may not be driving population change since there was a higher proportional increase in turbines in squares where Hen Harriers increased. It is therefore conceivable that a turbine density threshold may be a driver of population change.

Breeding parameters and wind energy in Ireland

Fernández-Bellon *et al.*'s (2015) analysis showed no significant differences between the breeding outputs of Hen Harrier nests that were located at different distances from wind turbines. However, non-statistically-significant lower nest success rates and productivity were observed within 1km of active wind turbines. Thus, there may be a negative effect on nest success extending to approximately 1km (see also Wilson *et al.*, 2015).

Monitoring carried out between 2008 and 2010 revealed a breeding success rate of 79.2% for Hen Harriers in territories where no wind energy developments were planned (n=53), compared with a success rate of just 16.7% in territories where wind energy developments were planned (n=18) (O'Donoghue *et al.*, 2011). The outcome of this research suggests that harriers associated with wind energy development proposal areas have a significantly higher failure rate than harriers nesting elsewhere. Productivity may also be reduced, as shown by O'Donoghue *et al.* (2011), at a single Hen Harrier territory when comparisons are made between pre- and post-construction periods (average of 2.63 young reduced to 1.27 young) over a 22 year period.

Breeding outcome (nest success or failure) may be impacted by the occurrence of turbines, as indicated by Fernández-Bellon *et al.* (2015), although the mechanisms for this are not clear. Empirical data from the RTD (NPWS, unpublished) and outcomes of breeding records from national surveys in 2005, 2010 and 2015 indicate that successful nests were up to 20% (average 12.9%; range 0.3 – 20.1%) further away from turbines than failed nests (Table 4). This also indicates that only a small number of either failed or successful nests are located within 1km of a turbine in each survey year (Table 4), which means that effects, if any, are either occurring at greater distances or, perhaps, are unrelated to turbines in the landscape. It is notable perhaps that nearly 14% of failures in 2010 surveys were within 1km of turbines (average 5.9%; range 0 – 13.6%) (Table 4).

Table 4. Turbine distance from breeding Hen Harrier locations in recent national survey years, based on all turbine data up to and including 2015 and breeding outcomes

	Survey year	2005	2010	2015
Successful pairs	**Average distance (metres)**	23,551.50	13,432.60	11,054.20
	Number of records	56	50	49
	Number within 1km	2 (3.6%)	3 (6.0%)	1 (2.1%)
Failed pairs	**Average distance (m)**	18,790.10	10,990.90	11,019.10
	Number of records	6	44	48
	Number within 1km	0 (0%)	6 (13.6%)	2 (4.2%)
	Proportional difference in distance between successful and failed pairs	20.1%	18.2%	0.3%

Note: Survey data in 1998-2000 was extracted on a year-by-year basis as examination of trends with multi-year data is confounded by the repeated sampling of same locations in different years.

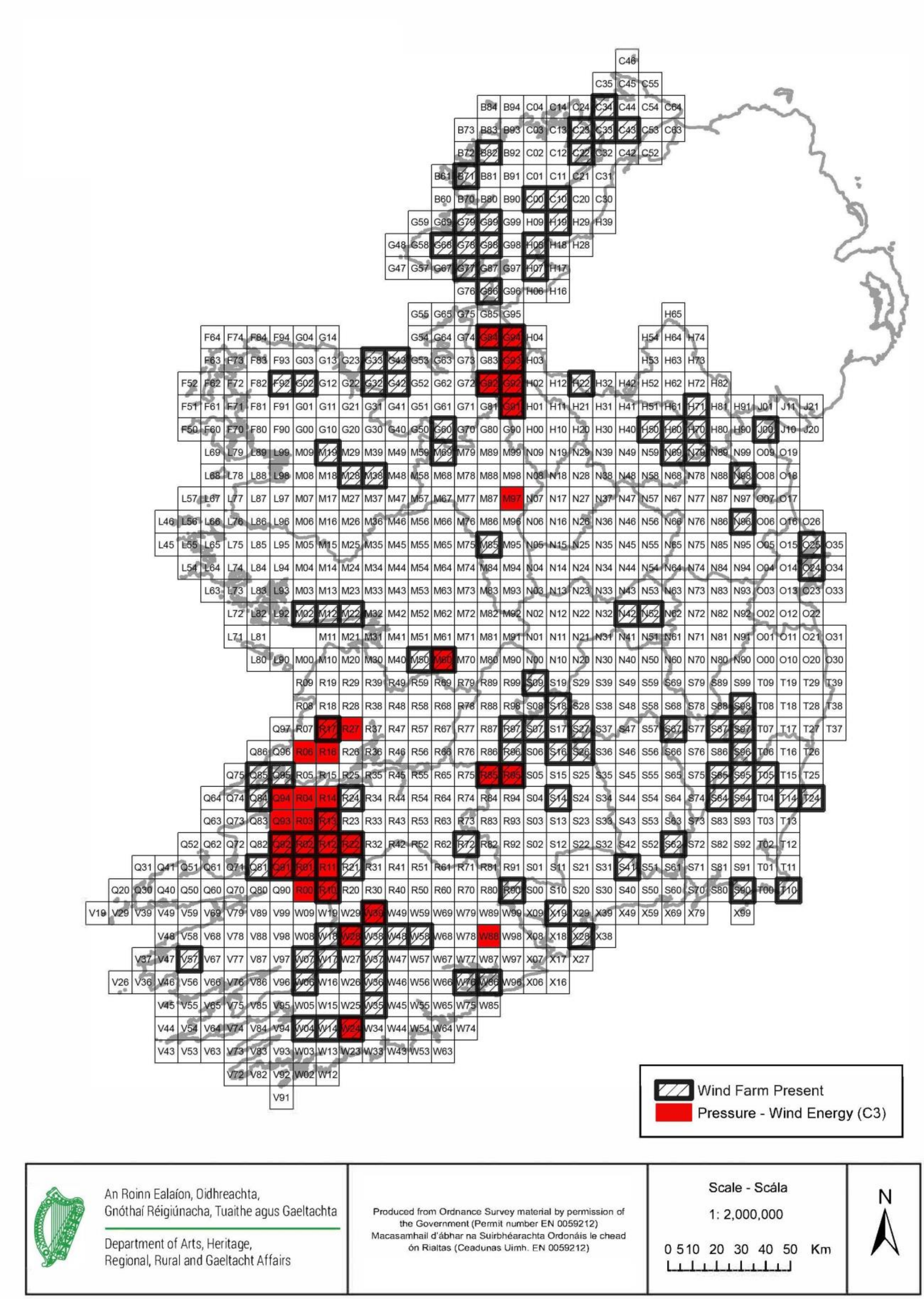

Figure 13. The presence of wind turbines (as derived from the RTD (NPWS, unpublished) and wind energy development pressure (C3, in accordance with Birds Directive Article 12 reporting) as recorded by surveyors (Ruddock *et al.*, 2016a)).

Collision risk and wind energy in Ireland

A small number of suspected Hen Harrier collisions have been documented in Ireland, (see Chapter 2) although it is also recognised that relatively few wind energy developments in Ireland have formal carcass-searching protocols (Fennelly, 2015). Therefore, collision incidences may well be under-recorded. Several studies elsewhere indicate that harrier species mortality at wind energy developments is relatively low (Smallwood and Thelander, 2004; Madders and Whitfield, 2006; Derby *et al.*, 2008) and not typically linked to bird abundance (Johnson *et al.*, 2000; Stewart *et al.*, 2005; Madders and Whitfield, 2006; Mabey and Paul, 2007), although Wilson *et al.* (2015) suggest that collision risk may be affected by proximity to nest sites. The spatial distribution of wind energy developments has a larger influence on the estimated number of collisions compared with the design of turbines, and therefore precluding wind energy developments from core breeding areas remains the most important mitigation measure (Schaub *et al*., 2020). The cumulative effect of the existing turbine network as well as potential future wind energy development in Ireland (SEAI, 2011) may lead to an increasing collision risk over coming years; this will be influenced by a range of factors including the level, nature and effects of repowering, and the scale of ambition for the expansion of the sector

Wilson *et al.* (2015) used observed Hen Harrier flight data to calculate an arbitrary 'typical' collision risk and estimated mortality for the 'average' wind turbine in Ireland with a rotor swept range of 25m (floor height) to 125m (ceiling height). The average breeding season collision estimate of Wilson *et al.* (2015) was between 0.778 and 2.477 birds over a 25 year wind energy development lifespan. It is not currently possible to draw a more robust generic conclusion for a national collision estimate using estimates of the number of wind energy developments or numbers of turbines since it is recognised that:

(i) not all turbines occur in Hen Harrier areas which may lead to an over-estimation of collision; but also

(ii) no estimates are available for the non-breeding season which may under-estimate mortality; and

(iii) collision risk can be highly site-specific and may be related to proximity of nest sites (Wilson *et al.*, 2015). There are 520 turbines (34.6% of 1,502 turbines) within the 2015 Hen Harrier breeding range and therefore, this would reduce overall estimated collision during the breeding season.

Wilson *et al.* (2015) reported Hen Harrier observations were below rotor height (25m) 83% of the time but within rotor-swept areas (25m – 125m) for 11.8% and above rotor height (>125m) for 5.4% of the time. Based on RTD (NPWS, unpublished), there were no recorded turbines of 25m floor and 125m ceiling height, and average floor height was 29.7m and ceiling 96.3m. 0.6% of turbines (n = 10) have a 25m rotor floor and 7.2% of turbines (n = 109) have a 125m ceiling height. Therefore, the rotor-swept area of Wilson *et al.* (2015) is larger than actual average rotor-swept areas and may be overly precautionary, although rotor swept areas generally ranged from 19m to 156m. Estimates of cumulative mortality in Ireland, based on the height bands of Wilson *et al.* (2015), may require re-analysis on the basis of observed flying heights from that study, actual turbine metrics now available (NPWS, unpublished; this study; and installations since 2016) and preferably, the inclusion of site-specific collision estimates (see Chapter 4).

A composite review of all available data may facilitate further analysis of cumulative collision mortality risk estimates for Ireland. By utilising and updating the turbine database now available (NPWS, unpublished; this review), it would be possible to produce a national collision risk model to establish the level of wind energy development -mediated mortality (see O'Donoghue, 2011; Ruddock *et al.*, 2012; 2016). It is noted, however, that collision mortality and risk estimates can be highly site-specific and may not be linked to abundance or detection rates from pre-construction surveys (Haworth and Fielding, 2012; see also Chapter 2), although such an estimate would be useful to inform indicative cumulative risk in Ireland and also allow assessment of future projects. Two suspected collisions in Ireland have occurred in the non-breeding season and there is an absence of flight data available for that time of the year, although it is suspected that flights may be routinely lower during it, due to the lack of higher elevation display flights that occur in the breeding season (O'Donoghue 2011; Wilson *et al.*, 2015).

Potential interactions of wind energy and Irish Hen Harrier SPA breeding populations

It has previously been reported that there were 17 extant wind energy developments within the SPAs, with a further 10 proposed in 2015 (Wilson *et al.*, 2015). Ruddock *et al.*, 2016a reported that four of the six SPAs held a total of 236 turbines within the boundaries and a further 44 were located within 500m of them. As noted earlier, wind energy development (C3) and power line (D3) pressures were reported (Figure 13) for four of the SPAs, Mullaghanish to Musheramore; Stacks, Stack's to Mullaghareirk, West Limerick Hills & Mount Eagle; Slievefelims to Silvermines Mountains and Slieve Aughties had. In the Slieve Blooms SPA, whilst no turbines were recorded within it, power lines (D3) were recorded as a pressure (Ruddock *et al*., 2016a).

This review estimates that, as of 2016, there were 319 turbines inside four of the six SPAs and 58 turbines within 1km of the SPAs (Table 4). Two SPAs, Slieve Beagh and Slieve Blooms, did not have any turbines in 2016 nor are there turbines within 1km of their boundaries. Neither were there turbines within 28.7km and 2.1km distance of these two SPAs, respectively, but there has been an increasing number of turbines within the other four SPAs over time (Table 4).

Prior to the Hen Harrier SPA designation process in 2007, there were already turbines located within the boundaries of two of the SPAs, namely Slieve Aughty Mountains SPA and Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle. Mullaghanish to Musheramore Mountains SPA had no turbines present until after 2010 (Table 4), although three turbines were located within 1km of the boundary between 2005 and 2010. As of 2016, there remain a small number of turbines within the SPA boundary and there have been an increasing number of turbines adjacent to it (within 1km of its boundary). Despite only a small number of turbines inside the boundary, nearly 10% of the SPA area was within a kilometre of one, at that time.

The Slieve Aughty Mountains have had the same number of turbines present from 2005 to 2016 *i.e.* prior to SPA designation. Therefore, it is unlikely that Hen Harrier declines in the Slieve Aughties in recent years (2005 – 2010 = 14.8% decline; 2010 – 2015 = 39.1% decline) are related to pressure from increasing numbers of turbines, although those present were installed in close proximity to a number of Hen Harriers territories at the time (Madden and Porter, 2007). A spatial redistribution and avoidance of this general area by Hen Harrier may have consequently occurred but further analysis is required to understand the reason/s behind the observed decline in numbers of breeding pairs in this area.

Similarly to Mullaghanish to Musheramore SPA, in the Slievefelim to Silvermines SPA there were a small, but increasing, number of turbines, both inside the boundary (covering a relatively small area of the site) and within 1km of it (Table 5), as of 2016. Between 2010 and 2015, there was an increase from four to 11 turbines within this SPA and an increase from one to six turbines within 1km of the boundary. With regard to the Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPA, nearly 20% of the area within the SPA boundary was within 1km of a turbine (Table 5) by 2016. There was also a 428% increase in the number of turbines between 2005 (pre-designation) and 2015 (post-designation), with a total of 227 turbines inside the boundary and a further 39 turbines within 1km.

As indicated by Fernández-Bellon (2015) and Wilson *et al.* (2015; 2016), if effects on Hen Harrier breeding success or breeding numbers may occur up to 1km from the nest site, then turbines beyond the SPA boundaries may be affecting the species within the designated sites, if there is suitable nesting habitat within this distance. Therefore, consideration of such *ex-situ* impacts is necessary. As of 2016, this *ex-situ* impact could be occurring at three SPAs, Mullaghanish to Musheramore; Slievefelims to Silvermines and at the Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle complex (Table 5). Also as of 2016, one hundred and sixteen other turbines occured across 14 other designated sites in Ireland. This includes six Natural Heritage Areas (NHAs; 83 turbines), one potential or potential NHA (3 turbines), and six SACs (30 turbines). Several other turbines occur in close proximity to some wetland SPAs (*e.g.* Cork Harbour SPA and Cahore Marshes SPA).

Table 5. The zone of potential influence & number of turbines at Hen Harrier SPAs at the time of National Surveys

	2000		2005		2010		2015	
Special Protection Area	Area (ha) of SPA within 1km of turbines	Number of turbines within SPA	Area (ha) of SPA within 1km of turbines	Number of turbines within SPA	Area (ha) of SPA within 1km of turbines	Number of turbines within SPA	Area (ha) of SPA within 1km of turbines (%)	Number of turbines within SPA
Mullaghanish to Musheramore Mountains 004162 (4,975.6ha)	0	0	0	0	7 (0.1%)	0 (3)	485 (9.7%)	2 (13)

	2000		2005		2010		2015	
Special Protection Area	Area (ha) of SPA within 1km of turbines	Number of turbines within SPA	Area (ha) of SPA within 1km of turbines	Number of turbines within SPA	Area (ha) of SPA within 1km of turbines	Number of turbines within SPA	Area (ha) of SPA within 1km of turbines (%)	Number of turbines within SPA
Slieve Aughty Mountains 004168 (59,435.65ha)	0	0	2,059 (3.5%)	79	2,059 (3.5%)	79	2,059 (3.5%)	79
Slieve Beagh 004167 (3,455ha)	0	0	0	0	0	0	0	0
Slieve Bloom Mountains 004160 (21,761.25ha)	0	0	0	0	0	0	0	0
Slievefelim to Silvermines Mountains 004165 (20,909ha)	0	0	12 (0.1%)	0 (1)	323 (1.5%)	4 (1)	752 (3.6%)	11 (6)
Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle 004161 (56,627.2ha)	1,139 (2.0%)	29	1,765 (3.1%)	43	6,201 (10.9%)	131 (23)	10,895 (19.2%)	227 (39)
Inside SPA	1,139 (0.7%)	29 (0)	3,836 (2.3%)	122 (1)	8,590 (5.1%)	214 (27)	14,191 (8.5%)	319 (58)
Outside SPA	8,806	169	22,115	365	54,829	830	86,268	1,183
Total	**9,945**	**198**	**25,951**	**487**	**63,419**	**1,044**	100,459	**1,502**

Ruddock *et al*. (2016a) identified areas in which wind energy development pressures were recorded across 268 surveyed 10km squares. Of the 55 10km squares within which the SPAs occur, there are 21 (38.2%) that contain wind turbines (NPWS, unpublished) and 16 (29.1%) that were considered to be under pressure from wind energy developments (Figure 13; Table 6). Four of these latter squares do not contain turbines (Figure 13) and as noted earlier, fieldworkers may have taken into account pressure from turbines in adjacent squares and near the SPA boundaries and/or may been aware of proposed wind turbines in those areas during their field surveys, potentially from preparatory works.

Table 6. The no. and % of 2015 10km survey squares and their breeding status with regard to turbine presence.

	SPA Status	Confirmed	Possible	Seen	Not seen	Total
Turbines	SPA	13 (61.9%)	2 (14.3%)	5 (23.8%)	1 (4.8%)	21
C3 Pressure	SPA	11 (68.8%)	1 (6.3%)	3 (18.8%)	1 (6.3%)	16

Potential interactions of wind energy and Irish Hen Harrier breeding populations outside of SPAs

Wilson *et al.* (2015; 2016) quantified the spatial overlap at the 10km square resolution based on the 2010 breeding survey (Ruddock *et al.*, 2012) and found that 28% of the range overlapped with Hen Harriers' breeding range, but no distinction was made between designated and non-designated areas. The majority of wind turbines (n = 1,183; 78.8%) in Ireland (NPWS, unpublished) are located outside the SPAs (Table 5; Figure 8).

Potential interactions of wind energy across the wider countryside

NPWS (2015a) defined a method by which important spatial clusters (or regional zones) of breeding Hen Harriers were identified, using the 2010 Hen Harrier survey data. These were subsequently updated by Ruddock *et al.* (2016b), using 2015 Hen Harrier locations (Figure 14). This method defined a series of polygons that were classified as either designated (contiguous with SPAs) or non-designated (beyond SPAs) regional breeding populations. There were fewer turbines (n = 42) recorded within the non-designated areas than the designated areas (n = 250; Table 7), with between 0% and 6.8% (average 1.7%) of the non-designated areas within 1km of turbines compared to 0% to 16.7% (average 6.9%) at SPAs (Table 7).

Within some of the SPAs, a relatively high percentage of turbines were noted (Table 7). Consequently, a relatively lower percentage of turbine coverage within non-designated areas and a greater number of pairs of Hen Harriers in these zones, when compared to the proportional turbine coverage, is noted (Table 7; Figure 15).

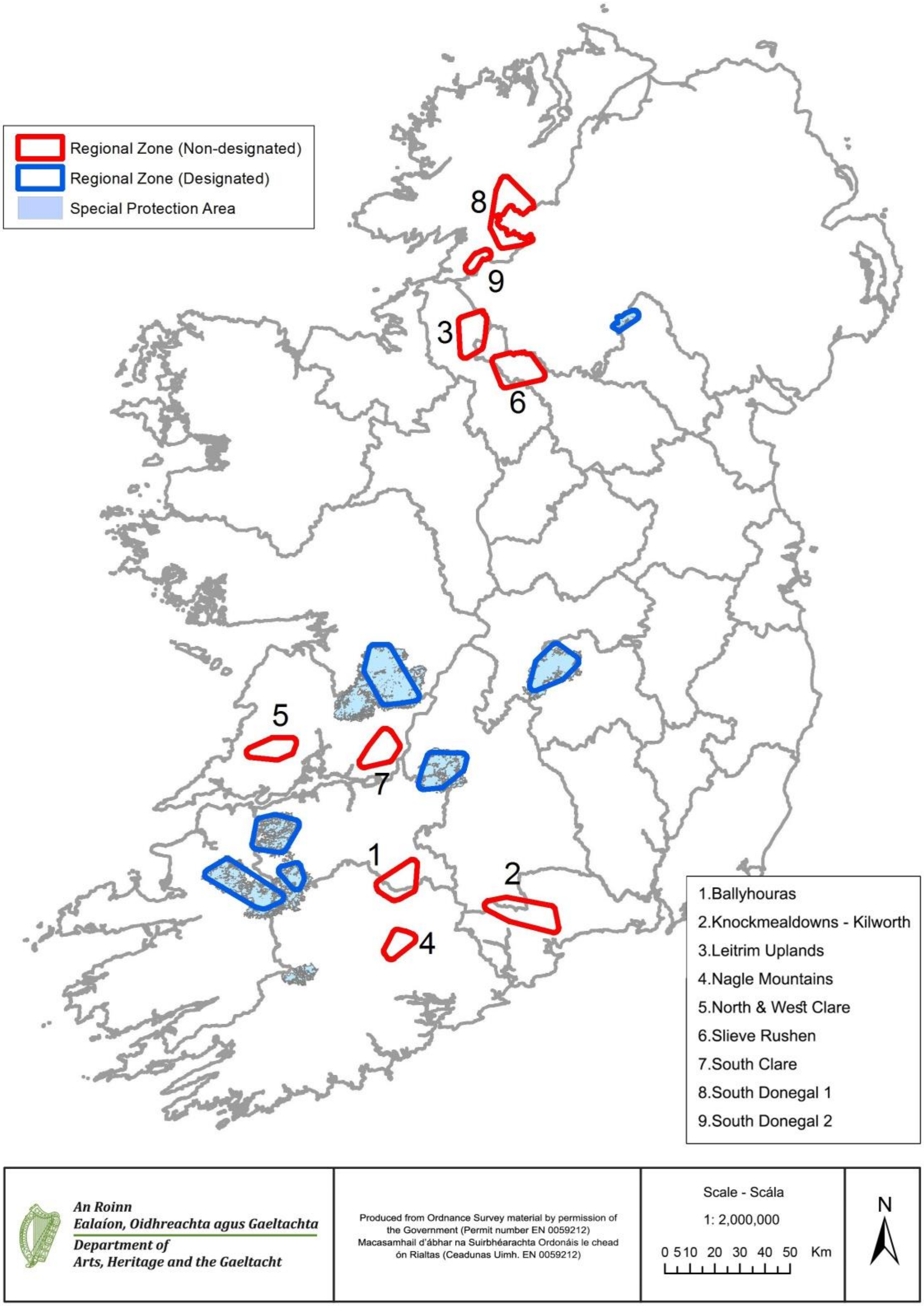

Figure 14. The distribution of relatively important breeding populations of Hen Harriers (*i.e.* designated and non-designated regional zones), as defined by Ruddock *et al.* (2016b), using 2010 and 2015 survey data.

Table 7. The characteristics of turbines located within the 2015 Hen Harrier important breeding population areas (or zones), and size (ha) of associated turbine buffers.

Zone (number of pairs)	Zone Area (ha)	Turbine Count	Sum Mw	Ave Mw	Ave Hub Height (m)	Ave Rotor Diameter (m)	Area (ha) covered by 2015 Turbine 1km Buffer	% of Regional Zone Covered
SPAs								
Aughty 1 (12)	33677.6	79	67.2	0.9	49.0	52.0	2059.6	6.1
Slieve Beagh (3)	4439.3	0	0.0	0.0	0.0	0.0	0.0	0.0
Slieve Blooms (12)	21564.7	0	0.0	0.0	0.0	0.0	0.0	0.0
Slievefelim 1 (10)	20821.9	0	0.0	0.0	0.0	0.0	171.4	0.8
Stacks North 1 (14)	21163.1	41	91.5	2.2	65.7	72.9	3210.0	15.2
Stacks North 2 (5)	7322.5	6	12.5	2.1	78.0	81.7	685.8	9.4
Stacks West & South (12)	30171.5	124	147.9	1.2	58.8	56.7	5035.2	16.7
Non-designated								
Ballyhouras (12)	16801.4	2	4.6	2.3	64.0	71.0	200.5	1.2
Knockmealdowns – Kilworth (7)	25234.3	0	0.0	0.0	0.0	0.0	0.0	0.0
Leitrim Uplands (7)	16443.9	4	9.2	2.3	64.0	71.0	521.2	3.2
Nagle Mountains (5)	9175.4	0	0.0	0.0	0.0	0.0	0.0	0.0
North & West Clare (8)	13154.0	13	11.1	0.9	65.0	70.0	893.2	6.8
Slieve Rushen (7)	21302.1	2	3.0	1.5	65.0	70.0	314.1	1.5
South Clare (7)	14952.3	0	0.0	0.0	0.0	0.0	0.0	0.0
South Donegal 1 (11)	24337.2	21	12.6	0.6	40.0	39.0	735.1	3.0
South Donegal 2 (3)	4532.4	0	0.0	0.0	0.0	0.0	0.0	0.0

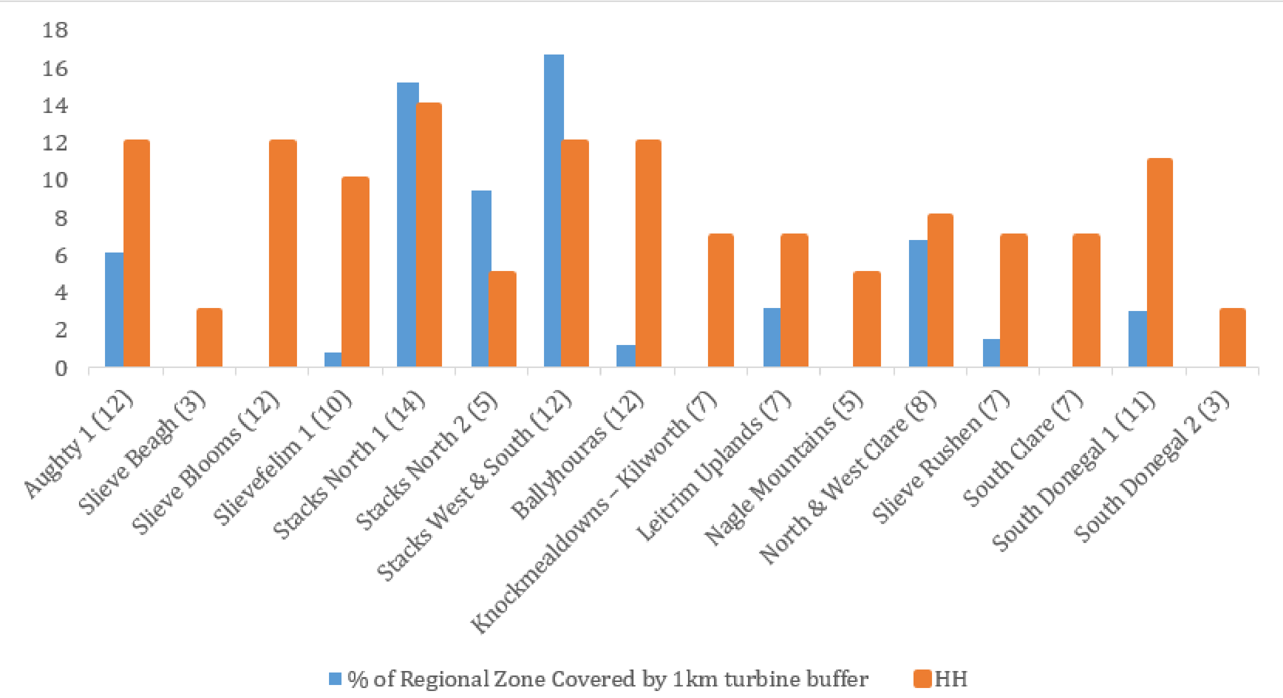

Figure 15. The number (y axis) of breeding Hen Harrier within designated and non-designated important regional breeding areas and the proportional areas within 1km of turbines.

Direct disturbance during the breeding season

During the 2010 and 2015 National Hen Harrier Surveys, both wind energy developments and power lines (which may or may not be related to the wind energy developments) were recorded by surveyors as sources of disturbance to breeding Hen Harrier. In 2010, there were five records of disturbance attributed to wind energy developments by surveyors in Cavan, Kerry, Limerick and Cork, and implicated in the outcome of those territories (Ruddock *et al.*, 2012). None of these five territories were reported as successful and two pairs were explicitly reported to have failed due to wind energy development-related factors. Construction, operational or decommissioning works may cause disturbance to Hen Harriers (see Chapter 2). O'Donoghue *et al.* (2011) also report disturbance (and displacement) due to wind energy developments.

Using empirical data, best practice and/or expert recommendations, avoidance distances have been defined with a view to minimising effects of wind energy developments and other potential sources of disturbance (see review by Ruddock and Whitfield, 2007). They ranged from <10m to 1,500m, indicating a wide variation in individual responses by Hen Harriers. It was also recognised that close-range reactions may be a result of Hen Harriers only flushing at close range to an observer but that the disturbance may have been detected by the harrier in advance of flushing; also, that some birds, *e.g.* non-habituated pairs or individuals, may respond to disturbance at very large distances.

There are a number of studies that recorded empirical data or made disturbance buffer recommendations for Hen Harriers, which ranged from 30m to 1,000m (Table 2). A summary of these studies is provided in Table 8 below. The majority of expert opinions (80%) suggested that significant disturbance responses were likely to occur within than 750m and thus, recommended a buffer of 500 – 750m. Taking the mean of these minimum and maximum figures equates to 475m – 670m and a median of 500 – 750m. Therefore, the recommendations of Whitfield *et al.* (2008) for a buffer of 500 – 750m seem pragmatic in order to provide protection from direct disturbance, although a wider buffer, >1km, to avoid direct disturbance may be practicable in order to reduce long-term effects on breeding parameters (Fernández-Bellon *et al.*, 2015) and mitigate potential population effects (Wilson *et al.*, 2015; 2016). Buffer distances should also take into account lines of sight from a nest and areas of flight activity, rather than being applied solely as radii from the possible sources of disturbance.

Table 8. Summary of literature that identifies displacement or disturbance distances and/or buffer recommendations for Hen Harrier.

Disturbance source	**Distance (range) (m)**	**Effect**	**Reference**
Forestry activities	500-1000m	Buffer recommendation	Currie and Elliott, 1997
Forestry activities	500-600m	Buffer recommendation	Petty, 1998
Observer	300-1000m	Disturbance	Garcia and Arroyo, 2002
Observer	100m	Mobbing	Garcia, 2003
Wind energy development	500-1000m	Displacement	Madders, 2004
Wind energy development	200-300m	Displacement	Madders and Whitfield, 2006
Wind energy development	500-1000m	Displacement	Bright *et al.*, 2006
Various	500-750m	Disturbance/buffer recommendation	Ruddock and Whitfield, 2007; Whitfield *et al.*, 2008
Wind energy development	500-1000m	Disturbance	Bright *et al.*, 2008a
Wind energy development	500m (52%)/ c1000m	Displacement (foraging)	Pearce-Higgins *et al.*, 2009a
Observer	30 -120m	Mobbing	Irwin *et al.*, 2012
Wind energy development	140 – 1,280 (median 537m)	Displacement (1 pair)	O'Donoghue *et al.,* 2011
Wind energy development	2,000m	Wind energy development sensitivity	Bright *et al.*, 2008a
Wind energy development	2,000m	Wind energy development sensitivity	McGuinness *et al.*, 2015

There are only a small number of analyses that examine or report on the effects of specific construction, operational or decommissioning wind energy development activities on Hen

Harriers. O'Donoghue *et al.* (2011) reports that a single territory was abandoned during the year of construction, that breeding success and breeding activity were reduced post-construction, and that avoidance distance increased.

Potential interactions of wind energy developments and Hen Harrier populations outside the breeding season

Habitat loss and disturbance at roost sites

There are few studies of the interactions between wind energy developments and wintering species (Devereux *et al.*, 2008), and particularly for Hen Harriers, although such an interaction may cause direct disturbance and/or indirect displacement and/or collision, similar to those that may occur during the breeding season. Human activities can cause abandonment of Hen Harrier roosts (Clarke and Watson, 1990; O'Donoghue, 2010).

The Irish Winter Hen Harrier Survey (IWHHS) is the main source of survey and monitoring data for Hen Harrier during the non-breeding period in Ireland, collecting information on the distribution and occupancy of roosts across the country since 2005. O'Donoghue (2010) reports a predominance of reedbeds and heather/bog habitats for winter roost sites up to 238m asl but the majority were less than 100m asl and more than half (53%) were less than 30m asl. O'Donoghue (2010) also reports a mean of 44.3 ± 8.3m asl for winter roost sites which is considerably lower than the turbine altitudes found in this review (253 ± 108.7m asl). There were 82 turbines (5.4%) recorded at less than 53m asl which indicates a relatively low altitudinal overlap with roost sites. It is also recognised that many of the breeding sites may remain occupied as wintering roost sites (B. O'Donoghue, pers. comm.) and the recent mean altitudes at which turbines occur may now be higher since winter roost data was last published (O'Donoghue, 2010). That study did not explicitly identify wind energy developments or turbines as a threat or pressure on roosts at that time, although they were listed as a general threat to Hen Harriers in Ireland (see also O'Donoghue *et al.*, 2011).

Wintering harriers were recorded across 403 10km squares (Balmer *et al.*, 2013) which equates to 46.4% of the 869 squares in Ireland. 88 of these 10km squares were known to contain winter roost sites (NPWS, 2015). An analysis of the RTD (NPWS, unpublished) shows that 1,036 turbines occur within 66 squares (16.4% of squares) within the species' known wintering range. Of the 88 squares known to contain winter roost sites, 22.7% of these contained between two and 43 individual turbines. That is, at the 10km grid level, nearly a quarter of the known winter roost distribution in Ireland contains wind turbines (Table 9; Figure 16).

NPWS (2015a) reports that the IWHHS had identified 96 confirmed roost sites and a further 13 suspected roost sites at that time. A more detailed analysis of roost sites would provide more relevant metrics to aid understanding of the interactions between wind turbines and wintering Hen Harriers. There would be particular value in the following:

(i) a spatial analysis of turbine proximity to winter roost sites and
(ii) establishment of the altitudinal overlap of winter roost sites with turbines; and
(iii) a comparison of winter roost and turbine habitats.

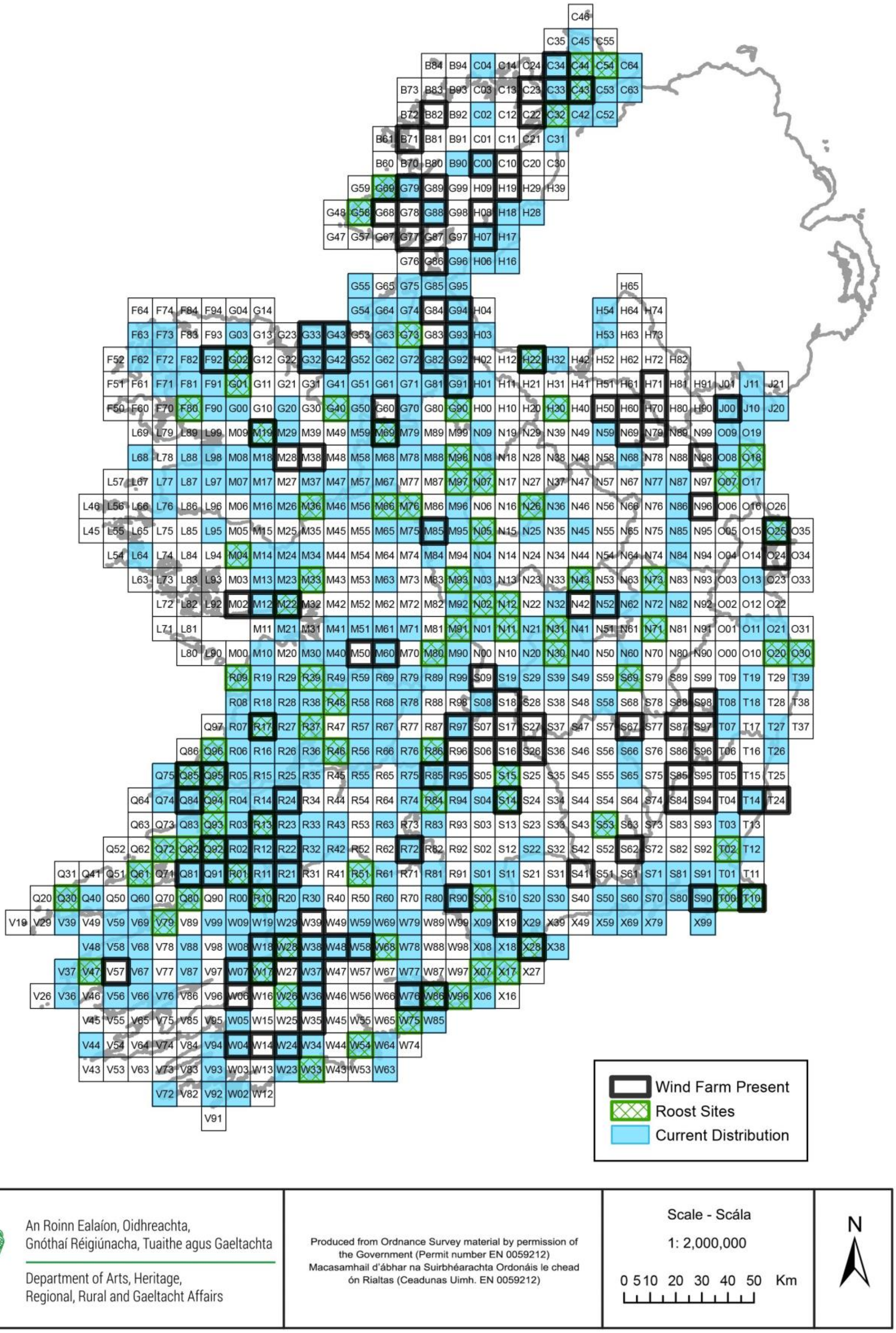

Figure 16. The distribution of wind turbines (2016), Hen Harrier winter roost sites and Hen Harrier winter records (Balmer *et al.*, 2013).

Table 9. Spatial overlap of Hen Harriers and numbers of turbines per 10km resolution, within winter distribution and winter roost range.

	Number of squares	Number of squares with turbines	Percentage of squares with turbines	Number of turbines	Average number of turbines	Min	Max	MW
Within winter range	403	66	16.4	1036	15.7	1	75	1698.9
Within winter roost range	88	20	22.7	306	15.3	1	43	446.1
Outside winter range	466	54	11.6	466	8.6	1	61	716.8

Loss of foraging habitat outside the breeding period

It is known that a proportion of the overwintering population of Hen Harrier in Ireland either remain on or transiently use the breeding uplands for foraging and roosting. Therefore, similar sources of habitat loss that have been identified for the breeding population (*e.g.* displacement from foraging habitat; see Pearce-Higgins *et al.*, 2009a) are also relevant to the species during the winter season, although they can more readily move away from the affected area during the winter.

Although studies that examine winter foraging habitat preferences are limited, it is likely that closed canopy forest and improved pastures that are actively avoided by foraging Hen Harrier during the breeding season are also of negligible importance for this species outside the breeding season. The pressure caused by wind energy developments on individual Hen Harriers outside the breeding season may be less obvious due to the perceived movement of birds to less exposed and lowland areas in winter, where fewer turbines occur (Figure 7). The magnitude of this pressure may not be as severe because (i) Hen Harrier are more widely distributed in the winter (Figure 3) and may be less dependent upon the breeding sites; and (ii) Hen Harrier are known to use a wider variety of habitats, including tillage, during the winter months. Further analysis of altitudinal overlap of wintering Hen Harriers and turbines would allow for an examination of the levels of spatial conflict.

While these pressures may be less pronounced outside the breeding season, the higher occurrence of turbines in non-breeding areas, or in habitats used in the winter, may still affect Hen Harrier. Satellite-tracking studies in Ireland and the UK have shown that birds will disperse up to 20km from roost sites during the day to forage on upland heath and rough grassland, often returning to the same areas frequently over a period of days, weeks and months (B. O'Donoghue and S. Murphy, pers. comm., cited in NPWS, 2015a). These patterns of dispersal may indicate that the dependence on foraging quality away from roosts, in areas of lowland and upland heaths, and marginal farmland, could be as important for winter survival as they are for reproductive success during the breeding season. Therefore, the avoidance of, or barrier effect response to, optimal habitats due to the presence of turbines may compromise winter foraging efficiency and thus over-winter survival. The effects of disturbance are likely, however, to be less constrained than they would be during the nesting period, although this could be exacerbated by disturbance at the roost sites.

Other potential interactions of wind energy and Hen Harrier populations

Habitats in which wind turbines are installed in Ireland

Research studies and national surveys have increased our knowledge of the importance of various habitats and their use by Hen Harrier during the breeding period (Wilson *et al.*, 2012; Irwin *et al.*, 2012; Barton *et al.*, 2006; Ruddock *et al.*, 2012; 2016). Although several studies report that Hen Harrier continue to utilise wind energy developments for foraging in Ireland (Madden and Porter, 2007; O'Donoghue *et al.*, 2011; Wilson *et al.*, 2015) and that a small number will nest within a few hundred metres (O'Donoghue *et al.*, 2011; this review), other research indicates potential avoidance of habitats due to wind energy developments (Pearce-Higgins *et al.*, 2009a). In order to examine wind turbine interactions with habitats, two analyses were undertaken as part of this review. Firstly, the turbine databases were compared to the SPA habitat database available from Moran and Wilson-Parr (2014), and then a wider analysis was undertaken, utilising CORINE (EPA, 2012) habitat data at the national scale.

Moran and Wilson-Parr (2014) data is relatively high resolution but is only available for the SPAs. An analysis of this data with the RTD (NPWS, unpublished) identifies that the majority of the 319 turbines within the SPAs are located within five main habitat types (Table 10). These five main habitats are:

- cutover bog;
- conifer plantations (>15 years old);
- conifer plantations (of unknown planting year);
- combined wet/dry heath; and
- rough grassland.

Moran and Wilson-Parr (2014) categorised the different habitat types as currently suitable for nesting or for foraging. Forty four point five - 62.7% of the SPA turbines occur in habitats which could be suitable for nesting Hen Harrier. Similarly, 60.2% -78.4% of turbines are located in habitats that are classified as suitable for foraging. Patterns of occurrence within different habitats varied within individual SPAs (Table 11); the most influential SPA driving the pattern was the Stacks complex, as it contains relatively higher numbers of turbines (Table 5).

Table 10. Habitats in which turbines are recorded within Hen Harrier SPAs, based on Moran and Wilson-Parr (2014).

Habitat Description	Habitat Code	Frequency of occurrence (n)	Percentage composition (%)	Suitable for nesting	Suitable for foraging
CUTOVER BOG	PB4	79	24.8	Yes	Yes
CONIFER PLANTATION 15 YEARS PLUS	FOR>15YR	63	19.7	No	No
CONIFER PLANTATION	FOR_UNK	58	18.2	Possible	Possible

Habitat Description	Habitat Code	Frequency of occurrence (n)	Percentage composition (%)	Suitable for nesting	Suitable for foraging
UNKNOWN PLANTING					
COMBINED WET DRY HEATH	HH	45	14.1	Yes	Yes
ROUGH GRASSLAND 50%PLUS COVER JUNCUS	RG	42	13.2	No	Yes
UNPRODUCTIVE CONIFER PLANTATION	UNPRO	10	3.1	Yes	Yes
IMPROVED AGRICULTURAL GRASSLAND	GA1	6	1.9	No	No
CONIFER PLANTATION 9 - 12 YEARS	FOR9_12YR	5	1.6	Yes	Yes
MOSAIC GRASSLAND CLUSTERED 30 - 39%	MG_C3	4	1.3	No	Yes
DRY/HUMID ACID GRASSLAND	GS3	2	0.6	No	Yes
CONIFER PLANTATION 13 - 14 YEARS	FOR13_14YR	1	0.3	No	Yes
CONIFER PLANTATION 4 - 8 YEARS	FOR4_8YR	1	0.3	Yes	Yes
FRESHWATER MARSH	GM1	1	0.3	No	Yes
SCRUB	WS1	1	0.3	Yes	Yes
UPLAND BLANKET BOG	PB2	1	0.3	Yes	Yes
TOTAL		319	100%		

Table 11. Habitats in which turbines are recorded within individual Hen Harrier SPAs in Ireland, based on Moran and Wilson-Parr (2014).

Habitat description	Mullaghanish Musheramore Mountain SPA		Slieve Aughty Mountain SPA		Slievefelim Silvermines Mountains SPA		Stack's - Mullaghareirks SPA	
	n	%	n	%	n	%	n	%
CUTOVER BOG			15	19.0			62	27.7
CONIFER PLANTATION 15 YEARS PLUS			24	30.4	4	36.4	34	15.2
CONIFER PLANTATION UNKNOWN PLANTING			38	48.1	1	9.1	18	8.0
COMBINED WET DRY HEATH	1	20.0	2	2.5			41	18.3
ROUGH GRASSLAND 50%PLUS COVER JUNCUS					4	36.4	39	17.4
UNPRODUCTIVE CONIFER PLANTATION							10	4.5

Habitat description	Mullaghanish Musheramore Mountain SPA		Slieve Aughty Mountain SPA		Slievefelim Silvermines Mountains SPA		Stack's - Mullaghareirks SPA	
	n	%	n	%	n	%	n	%
IMPROVED AGRICULTURAL GRASSLAND	2	40.0					7	3.1
CONIFER PLANTATION 9 - 12 YEARS							5	2.2
MOSAIC GRASSLAND CLUSTERED 30 - 39%					1	9.1	3	1.3
DRY/HUMID ACID GRASSLAND	2	40.0					1	0.4
CONIFER PLANTATION 13 - 14 YEARS							1	0.4
CONIFER PLANTATION 4 - 8 YEARS							1	0.4
FRESHWATER MARSH					1	9.1		
SCRUB							1	0.4
UPLAND BLANKET BOG							1	0.4
TOTAL	**5**		**79**		**11**		**224**	

This review also utilised the most recently available CORINE (EPA, 2012; Lydon & Smith, 2014) habitat data, at the time of the analysis, to examine the broad types of habitats where turbines are installed across Ireland, both within and without the Hen Harrier SPA Network. Similarly to within the SPAs alone, the majority of turbines have been installed in peat bog habitats (48.1%) (Table 12) and a minority of turbines in the wider area occur within urban or more densely human-occupied habitats. All of the key seven habitats in which turbines most frequently occur (Table 12) could be useful to breeding or wintering Hen Harriers, although the resolution of these data and the quality of such habitats cannot be examined from these data sources. O'Donoghue (2010) reports the usage of reedbeds and upland (heath) areas for roosting, but further analysis of habitat co-occurrence would enable a more detailed examination of wintering roost areas and wintering foraging areas.

Table 12. CORINE Habitats (EPA, 2012) in which turbines are recorded in the wider countryside

CORINE habitat description	CORINE Code	Number of turbines	Percentage of turbines (%)
Peat Bogs	412	722	48.1
Pastures	231	311	20.7
Transitional woodland shrub	324	242	16.1
Conifer forests	312	93	6.2
Land principally occupied by agriculture	243	64	4.3
Non-irrigated arable land	211	32	2.1
Moors and heathland	322	26	1.7
Green urban areas	141	5	0.3
Beaches, dunes and sand plains	331	2	0.1
Industrial or commercial units	121	2	0.1
Discontinuous urban fabric	112	1	0.1
Complex cultivation pattern	242	1	0.1
Mixed forest	313	1	0.1

The erection of turbines within suitable nesting habitat (either within SPAs or in the wider countryside) may cause displacement of Hen Harriers from suitable habitat. Similarly, the placement of turbines within suitable foraging habitats may cause avoidance (Pearce-Higgins *et al.*, 2009a) and create barriers to movement. The indirect loss of usable breeding habitat due to proximity to wind turbines can be a result of displacement or avoidance behaviour. That is, Pearce-Higgins *et al.* (2009b) found that an average avoidance of 52.5% occurred at 500m resolution, although this ranged from -1.2% to 74.2% which would indicate that no avoidance, theoretically, would occur at 1km and thus, avoidance around turbines for foraging birds would extend to approximately 1km.

The reduction of habitat suitability by the construction and/or operation of a wind energy development within Hen Harrier ranges could lead to a reduction in food supply and such changes may reflect the indicative changes in breeding parameters observed by Fernández-Bellon *et al.* (2015) and Wilson *et al.* (2015) at 1km distance. Whilst Wilson *et al.* (2015) only observed small changes in prey abundance (at circa 100m from turbines), the wider avoidance of foraging habitats could have consequential effects on breeding success or productivity and may lead to gradual population declines over time.

As provisioning Hen Harriers forage greater distances in forested landscapes in Ireland compared to distances indicated by studies from other countries (Arroyo, 2006; Irwin *et al.*, 2012; Arroyo *et al.*, 2014), habitat connectivity is therefore likely to be an important consideration in wind energy development management and spatial planning for Hen Harriers in Ireland. Habitat fragmentation could also occur, as manifested by the barrier effect of wind turbines and/or overhead power lines (OHLs) and associated wind energy development infrastructure, though OHLs are used much less frequently in wind energy developments in Ireland, than previously (Eirgrid, pers.comm and ESB Networks, pers. comm.). This may affect provisioning Hen Harriers that are nesting in landscapes with high proportions of wind turbines and that are actively being avoided. Consequently, Hen Harriers may have to increase foraging periods to meet their own nutritional demands or those of their nestlings. Pearce-Higgins *et al.* (2009b) found a significant distributional effect of turbines on Hen Harriers but no significant effects of distribution of tracks or transmission (power line) infrastructure were noted.

The prevalence of wind turbines within foraging habitats may affect their profitability and hen harrier may have to travel larger distances to access other habitats, possibly increasing foraging time, energetic expenditure and range (see Ruddock *et al.*, 2008). Wind turbines can result in reduced habitat quality and extent (*e.g.* WINDHARRIER findings in relation to small bird abundances (Wilson *et al.*, 2015)), thereby limiting foraging, nesting or even roosting resources. This could explain the indicative negative associations observed by Wilson *et al.* (2015; 2016) on both breeding parameters and population decline, albeit there are other potential confounding factors. Whilst Fernández-Bellon *et al.* (2015) indicates that some breeding parameters may be affected at 1km, other research indicates that foraging behaviour of breeding pairs can be influenced by habitat changes at distances up to 3km from the nest (Amar *et al.*, 2004; Arroyo *et al.*, 2009) and this could conceivably be larger based on average avoidance distances of 5-10km from extant turbines in 2015 (this review).

Arroyo *et al.* (2009) reported that human-wildlife conflict between the conservation of Hen Harriers, and the location of wind turbines for renewable energy generation, had increased (see also Madders and Whitfield, 2006). An understanding of foraging range and habitat selection can be useful in reducing this conflict by guiding the placement of turbines into areas that have the lowest quality habitat for foraging harriers, or managing habitats within existing wind energy developments to reduce collision risk (SNH, 2016).

Wind Energy Development Sensitivity Analysis

The examination of species sensitivity to wind energy developments in order to inform spatial planning is a recognised tool for minimising conflict (Bright *et al.*, 2008a and 2008b). In Ireland, Tierney *et al.* (2012) and McGuinness *et al.* (2015) produced a sensitivity map that included consideration of Hen Harriers. This map was compared to the turbine database (1,502 turbines; RTD, 2016):

- three turbines (0.2%) were identified within the high risk category;
- 246 turbines (16.4%) within the medium sensitivity category and
- 564 turbines (37.5%) within the low sensitivity category (Figure 17).

The remainder of turbines were in areas with no data available *i.e.* no known sensitivities for the species analysed. There were 574 turbines (38.2%) located within the areas that had been identified as either medium or low sensitivity specifically for Hen Harrier, within 11 counties (Cavan, Clare, Cork, Donegal, Galway, Kerry, Leitrim, Limerick, Roscommon, Tipperary and Waterford) (See Tierney *et al.* (2012) for further details on the methodology used).

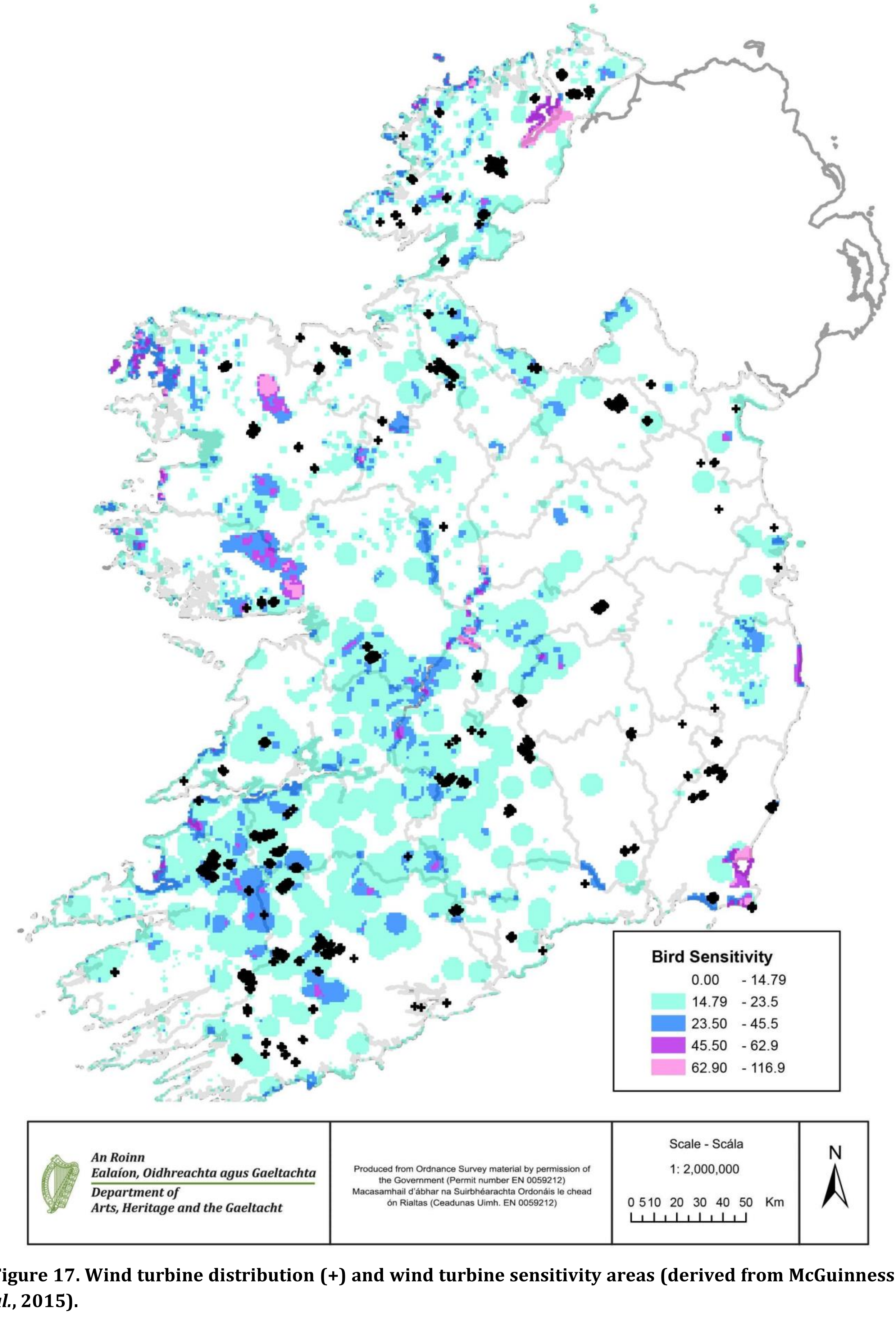

Figure 17. Wind turbine distribution (+) and wind turbine sensitivity areas (derived from McGuinness *et al.*, 2015).

CHAPTER 4: SUMMARY OF INTERACTIONS & FUTURE CONSERVATION MANAGEMENT OPTIONS

Introduction

This final chapter summarises the potential effects of wind energy development on Hen Harrier in Ireland and also sets out a series of options for the conservation of the Irish Hen Harrier population that are relevant to the wind energy sector. These options have been developed further through discussions with the Inter-Departmental Steering and have been integrated into the cross-sectoral Hen Harrier Threat Response Plan (NPWS-DHLGH, 2021).

The previous chapters have set out how the ambitious targets relevant to Ireland's renewable energy policy have resulted in an unprecedented level of wind energy development construction since 2000 and how demand for this development is likely to continue. The previous chapters have also detailed how such developments, at the project level or cumulatively, could affect individual Hen Harriers as well as site, regional and national population levels.

Summary of interactions

With regard to the conservation management of the Irish Hen Harrier population, there are several effects that may arise as a result of potential interactions with the wind energy sector. These are as follows:

- (i) loss of, or displacement from, foraging and nesting habitat during the breeding season;
- (ii) direct disturbance of nesting and roosting birds;
- (iii) loss of, or displacement from, winter foraging resources and roosting habitat; and
- (iv) risk of bird mortalities through collisions with turbines.

While these will be expanded on below, it is first useful to summarise the pattern of wind energy development and the habitats within which they are installed, the recorded distribution of the Hen Harrier across Ireland, and possible associated population-level responses.

Overlapping distributions and population level impacts

In 2015, breeding Hen Harrier territories (*i.e.* confirmed and possible breeding records) were recorded across 83 10km grid squares in Ireland. Over 32% of these squares overlapped with at least one wind energy development. This percentage overlap has increased nearly fivefold since the original national survey was conducted in 2000; meanwhile, the breeding harrier population is estimated to have declined over this period.

Using the RTD (NPWS, unpublished), it is calculated that almost 82% of turbines were located in the 100–400m altitudinal range; 92% of Hen Harrier territories recorded in 2015 were located in the same range. Over 66% of turbines and almost 60% of Hen Harriers occurred between the 200 and 400m contours. As described earlier, as of 2016, 44.5% - 62.7% of the SPA turbines occurred in habitats that could be suitable for nesting Hen Harrier. Similarly, 60.2% - 78.4% of turbines are located in habitats that are classified as suitable for foraging.

The most recent Bird Atlas (2007-2011) recorded harriers during the winter period across 403 10km squares; 88 of these 10km squares are known to contain winter roost sites (Balmer *et al.*, 2013; NPWS, 2015a). It has also been calculated that, as of 2016, over 1,000 turbines had been installed across over 16% of the known wintering range of the Hen Harrier (NPWS, unpublished).

For the WINDHARRIER study, Fernández-Bellon *et al.* (2015) assessed the breeding performance of Hen Harriers across Ireland in relation to wind energy development. Several measures of breeding performance were investigated and no statistically significant relationships were found between these breeding parameters and distance of the nest from the nearest wind turbine, although for those nests observed, nest success was lower within the closest distance band (0-1km) to turbines. Fernández-Bellon *et al.* (2015) conclude that these findings support earlier research that highlighted the importance of areas within a 1 km radius of raptor nests to breeding success.

Also for the WINDHARRIER study, Wilson *et al.* (2015) examined Hen Harrier population trends in relation to wind energy development in Ireland from 2000 to 2010, and noted that considerable overlap occurs between Hen Harrier breeding distribution and the location of wind energy developments. They reported "*A weak negative relationship was identified between wind farm presence and change in the number of breeding Hen Harrier pairs in survey squares between 2000 and 2010. However, the available evidence suggests that this was not a causative relationship but that local factors not included in the current study may have been responsible for the observed changes in Hen Harrier numbers within the survey squares. Furthermore, Hen Harrier population trends were negatively affected by a complex interaction between wind farm developments and the proportion of land between 200m and 400m above sea level*".

Loss of, or displacement from, foraging and nesting habitat during the breeding season

During the breeding season and beyond, the diet of Hen Harrier consists of small birds and small mammals. Wilson *et al.* (2015) identified that the densities of forest birds were significantly lower within 100m of wind turbines; and that densities of open-country bird species were also found to be lower at wind energy development sites, but that these differences were independent of distance to wind turbines. Therefore, lower densities may be due to larger-scale effects of wind energy developments.

Examining the foraging preferences of adult birds during the breeding season and differences between wind energy development and control sites, Wilson *et al.* (2015) highlighted the importance for Hen Harriers of open habitats that hold high diversity and densities of prey species (rough grassland, natural grasslands, scrub and peatland).

Pearce-Higgins *et al.* (2009b) provide evidence of significant Hen Harrier avoidance of apparently suitable habitat within 250m of turbines, with a predicted 53% reduction of Hen Harrier flight activity within 500m of turbines, assuming that modelled habitat usage is proportional to breeding density. However, Haworth and Fielding (2012) examined Harrier flight activity data from five wind energy developments and a more limited level of avoidance is suggested, concluding that Harriers are displaced at relatively smaller scales of between 0-100/200m (Haworth and Fielding, 2012).

The wider implications of these findings of displacement or avoidance effects need to be considered in relation to their potential effects on the Hen Harrier population at the national level. It is estimated that, as of 2016, 21% of all turbines in Ireland occurred within the breeding Hen Harrier SPA Network. The number of turbines within 1km of the boundaries of these SPAs had also increased, as set out earlier. Turbines have also been permitted in undesignated areas that have previously or continue to support breeding Hen Harrier. The review also indicates that, as of 2016, turbines outside the SPA network were predominantly located across peat bogs (48%), as well as there being a predominance of turbine installation in open habitats over which harriers are known to forage. Within the SPAs, as of 2016, over 50% of the turbines were installed over heath-bog and/or rough grassland.

Direct disturbance of nesting and roosting birds

The presence of operating wind turbines can exert a displacement pressure on foraging and nesting harriers. The presence of ancillary activities, including construction and maintenance activities, near nest and roost sites can elicit direct responses from birds. This disturbance may manifest itself in the temporary abandonment of the area by nesting or roosting birds. Depending on the timing, intensity and recurring/chronic nature of the source of the disturbance, birds may abandon the nesting and/or roosting site entirely. For Hen Harrier, Ruddock and Whitfield (2007) suggests the implementation of a minimum set-back distance of 500 - 750m in order to minimise the potential impacts of human activity on nesting attempts.

Loss of, or displacement from, winter foraging resources and roosting habitat

An examination of available data at the 10km level shows that almost one quarter of the known winter range of Hen Harrier in Ireland overlaps with wind energy developments. Although research on the impacts of wind energy developments on harriers outside of the breeding season is very limited, it is likely that some level of turbine avoidance by foraging birds occurs and therefore, some level of foraging habitat loss has occurred as a result of the development.

Risk of bird mortalities through collisions with turbines

A review of the relevant scientific literature on the collision risk of harriers with turbines indicates that the species is probably at low risk of collision generally, given the low altitude of the majority of its flight activity. The WINDHARRIER report noted that harriers at wind energy developments spent 12% of their flight time within wind turbine rotor-sweep height, while the amount of time spent by juveniles flying at this height was negligible; thus, it was concluded that the overall collision risk to harriers during the breeding period season was low. However, as noted earlier, since 2015, and even in the absence of a robust system for carcass searches on wind energy developments, there have been three probable/confirmed incidences of Hen Harrier mortality caused by turbine strike and one possible case reported to NPWS-DHLGH. This suggests that collision risk for this long-lived species, with a low reproductive output, may increase along with any increase in wind energy developments.

Wind Energy and Hen Harrier Conservation

Through the HHTRP process, various conservation actions can be recommended with a view to reducing pressures and threats on the Hen Harrier in Ireland. Specifically with regard to wind energy development, it is important to ensure that the integrity of Hen Harrier SPAs are not adversely affected by the individual and cumulative effects of wind energy developments and other plans, projects and pressures, *e.g.* by the reduction of the extent and/or quality of the habitats necessary to support the breeding Hen Harrier population.

In the planning of future wind energy developments, appropriate attention also needs to be given to allowing for a sufficiency of suitable breeding Hen Harrier habitat outside of the SPA network. The non-breeding/overwintering aspects of the species' life cycle also need to be considered in order to ensure that winter roosts and adequate foraging areas are maintained.

Improving the available evidence base for the assessment of future wind energy developments

Projections show that an increase in both new development and repowering of onshore wind energy developments is both likely and necessary in order to meet renewable energy targets (SEAI, 2018). Therefore, it can be anticipated that there is likely to be ongoing, and possibly increasing, interest in the development of wind energy in areas that also happen to be important for Hen Harrier, both outside and within SPAs. A greater understanding of the use and suitability of habitats in these areas for Hen Harriers is necessary to improve understanding of the ongoing and future risks to the population.

The WINDHARRIER report (Wilson *et al.*, 2015) provides an extensive suite of research on wind energy developments in Ireland that has been used to both inform this report and widen understanding of Hen Harrier and wind energy development interactions. It also sets out useful recommendations, some of which are similar to the management options set out in this chapter. In particular, it provides a useful review of ornithology survey guidelines and recommendations for the implementation of standardised guidance for surveys.

In order for proposed wind energy developments, or the repowering of existing wind energy development, to be assessed for potential impact on the Hen Harrier population, it is important that sufficient levels of robust data and knowledge are collected by, and available and accessible to, developers and agents acting on their behalf, so that fit-for-purpose assessment documents can be produced (*e.g.* Environmental Impact Assessment Reports, Natura Impact Statements and Environmental Reports). It is also important that these data are readily available and standardised so that decision-making authorities can conclude the various assessment processes, to the standard required.

Recommendations are as follows:

- In order for ecological data from different wind energy developments to be comparable and aggregated for efficient strategic level analysis, the data collected needs to conform to particular standards. The production and adoption of best practice guidance in relation to the design and undertaking of bird surveys at the appropriate scales, in order to inform fit-for purpose assessments and post-construction monitoring actions, would be of significant benefit. This would lead to an increase in the availability of data from comparable pre- and post-construction studies, including any carcass searches that are occurring.

- Easy access to project-level assessment documentation, including pre- and post-construction monitoring data, would further help in the assessment of in-combination and cumulative effects on Hen Harrier populations. The development of a facility to receive, store and report out on suspected bird collisions would also be a useful resource, with regard to providing data from both monitored (with formal carcass searches) and unmonitored (*i.e.* ad-hoc carcass recoveries) wind energy development.
- National Hen Harrier breeding surveys at five-yearly intervals need to continue for, at least, the medium term. The data derived from these surveys provides contemporary population estimates at both the SPA and national levels. It also enables the updating of other resources *e.g.* the production of updated maps of areas that have a higher likelihood of holding nesting pairs (*i.e.* HLNAs). These can be used as a tool to minimise potential disturbance events during the breeding season.
- The information presented in this report, and its implications for Hen Harrier breeding success, displacement *etc.* should be taken into account by parties involved in the ecological assessment (*i.e.* SEAs, AAs, and EIAs) of proposed wind energy developments, their repowering and associated or supporting policies, plans and programmes. This should include consideration of their potential effects on Hen Harrier outside the SPA network, particularly in non-designated regionally important zones, as required by Article 5 of the Birds Directive.
- Building on the work done by the SEAI, a spatial turbine database (RTD) has been further developed to support the development of this report (NPWS, unpublished). To promote effective cumulative level assessments, including collision risk modelling at various scales, the RTD needs to be further validated and maintained into the future, including through the addition of locations of recently-installed turbines. The RTD would be further strengthened if information relating to proposed, contracted or planned future wind energy developments was integrated.
- Further work is needed to gain a better understanding of the ecology of Hen Harrier outside the breeding season. More comprehensive and centralised knowledge on the characterisation and distribution of roost sites and wintering habitat use is also warranted. The fact that the possible Hen Harrier collision events occurred during the autumn/winter period is of particular relevance here.
- Hen Harrier habitat-offsetting works have been permitted as part of several wind energy developments. Focused research on the efficacy of such works would not only increase the planning authorities' confidence as to whether such works are effective in supporting the Hen Harrier, but furthermore, such research may also provide opportunity to provide guidance for the development of the most effective measures to minimise effects of wind energy developments on Hen Harrier.
- The production of a high-resolution habitat map for Ireland would help to inform Hen Harrier habitat suitability modelling work at the national level, as well as the production of more robust assessments and spatial planning.

- The implications of this review's findings, for the availability and quality of Hen Harrier habitat in the SPAs, should be reflected appropriately in the site-specific conservation objectives for those sites, and their associated conservation measures, as required under the Birds Directive.

Spatial Planning Policy Development and the Wind Energy Sector

In parallel with the need to increase the evidence-base to inform future wind energy development proposals, further clarity should be brought to bear on spatial planning and land-use policy.

The HHTRP forestry sector report (NPWS, 2015a) shows that, as of 2015, over 50% of the six breeding Hen Harrier SPAs was under forestry management. The report also estimates that, for the subsequent 10 to 15 years, the extent of the forest that will be usable by Hen Harrier is likely to decline. The HTTRP agricultural sector report (NPWS, 2015b) highlights that various drivers are increasing the likelihood that the extent of farmed high quality Hen Harrier habitats will not increase in the near future unless there is direct intervention. For instance, within the SPA network, the establishment of conservation initiatives (such as the Hen Harrier European Innovation Partnership (EIP)), as well as the implementation of rotational forest management processes, should result in a redistribution of Hen Harrier breeding locations (both nesting and foraging) in the medium term.

As set out previously, some Hen Harrier SPAs contain relatively large numbers of wind turbines and there will be a considerable demand for, and acceleration of, wind energy developments over the coming years in order to meet renewable energy targets. Because of their interactions, the installation of wind energy developments in areas important for Hen Harriers may constrain opportunities for the co-location of the targeted conservation measures that are needed to restore sufficient suitable habitat for a stable and adequately-sized breeding population in the SPA Network, *i.e.* because the presence of the wind energy development may undermine the efficacy of the conservation measures.

As mentioned earlier, the creation of habitat to offset the effects referred to above has been determined not to be mitigation (in the meaning of a Habitats Directive Article 6(3) assessment), but is rather a measure to be assessed pursuant to Article 6(4) (*i.e*. compensation) (Supreme Court, 2016; ECJ, 2018). The Advocate General considered the question arising as providing a valuable opportunity to clarify its Article 6 case law "*given the need to reconcile the Member States' increasing use of renewable energy sources, such as wind power, and the protections afforded to habitats and species, such as the hen harrier*" and acknowledged the importance of both ambitions (Advocate General Tanchev, 2018). The need to apply the precautionary principle in appropriate assessments has also been enshrined in ECJ case law (*e.g*. where effects may arise but have not been proven) (*e.g.* Waddenzee Judgment (ECJ, 2004). Public authorities shall give consent to a plan or project, or adopt a plan or project, under Article 6 (3) of the Habitats Directive, only after having determined that it shall not adversely affect the integrity of a European site; furthermore, appropriate assessments should "*include complete,* *precise and definitive findings and conclusions that are capable of removing all scientific doubt as to the effects of the proposed development on ... [sites] concerned*" (High Court, 2014).

Based on this report's review of available studies and best available knowledge, it can be concluded that the development of a wind energy development in, or immediately adjacent to, Hen Harrier habitat will result in some loss and/or reduction in quality of existing or current breeding habitat, through effects on, for example, breeding success and prey availability, which may result in negative changes to breeding productivity.

Thus, in line with the requirements of Article 6(3) and current case law concerning its application, project proposals (*e.g.* a proposal for new wind energy development, a proposal to repower an existing wind energy development, or a proposal to extend the operational life of a wind energy development through a new planning permission), that may affect the integrity of a Hen Harrier SPA will need to be able to demonstrate, with good quality, objective and reliable scientific evidence, that they will not adversely affect site integrity and its conservation objectives (*e.g.* result in significant mortality, displacement or affect the quality or availability of Hen Harrier breeding habitat, prey availability, and breeding success), including by taking into account the population status and trends for the species. This needs to be done in a manner that removes scientific doubt as to the effects that may arise, in combination with other plans and projects.

Relevant projects, plans or programmes, such as wind energy policy statements, strategies or frameworks that are developed, and their associated necessary environmental assessments (*i.e.* SEA, AA), should also reference and address the findings of this report.

Stakeholders could positively contribute to the robust assessment of the effects of wind energy development on Hen Harrier through a number of actions, including the following:

- Pre-application discussions with relevant stakeholders can identify potential nature conservation conflicts at an early stage and prevent/reduce both cost and time implications for all parties.

- Use and build on tools already developed to improve and to inform spatial planning and appropriate wind energy development siting, such as those referenced earlier in the report. This includes the long term maintenance and updating of the web resource that collates local authority wind energy strategies, the LARES methodology, map viewer and online tool.

- The production of sector-specific guidance on the assessment of the implications of proposed wind energy developments and repowering for Hen Harrier would be beneficial to inform the planning application process and decision-making. This would assist wind energy developers and operators, their ecologists, contractors and consultants, as well as competent authorities.

- In addition, in order to improve the effectiveness of avoidance and/or offsetting measures, a tool-box approach could be developed, following the undertaking of any necessary research (see earlier Recommendations). Such avoidance and/or offsetting measures *could* include:

- The avoidance of turbine installation on areas of open heath/bog habitat as such habitats are likely to be of more long-term benefit to harriers than conifer plantations would be. This would preferably be informed by Irish Hen Harrier habitat modelling work and/or a national habitat map to enable specific targeting.
- The avoidance of wind energy development on or immediately adjacent to important winter roost sites.
- Consideration of how best to minimise collision risk, *e.g.* to manage the habitat in the immediate footprint of turbines in a way that reduces its residual attractiveness for use by Hen Harrier, as well as turbine design *etc*.
- Development of a methodology for best practice in post-construction monitoring (including the setting of a minimum level required) and application of results to inform and adapt ongoing post-construction mitigation measures.
- Avoidance of disturbance stimuli to breeding and/or roosting birds.

These measures could also be usefully supported by:

- Optimisation of the effectiveness of Construction Environmental Management Planning (CEMP) and the use of on-site Ecological Clerk of Works (ECoW) to oversee the implementation of mitigation measures, where appropriate.
- Development and implementation of Wind Energy Development Standard Operating Procedures designed to minimise and avoid Hen Harrier disturbance events that may arise from day-to-day wind energy development activities and scheduled maintenance operations, along with associated outreach activities to relevant professionals.

REFERENCES

Note: Key references are highlighted in grey

AEC (2012). Freasdail Wind Farm Environmental Statement 2012 Chapter 8. Arcus Renewable Energy Consulting Ltd., 507-511 Baltic Chambers, 50 Wellington Street, Glasgow.

Advocate General Tanchev (2018). Case C-164/17 Edel Grace & Peter Sweetman v An Bord Pleanála. Reference for a preliminary ruling Environment Directive 92/43/EEC Article 6(3) Directive 2009/147/EC: *Assessment of the implications of a wind farm project for a special protection area Hen harrier (Circus cyaneus) Mitigation measures*.

Amar, A., Arroyo, B., Redpath, S. and Thirgood, S. (2004). Habitat predicts losses of red grouse to individual hen harriers*. Journal of Applied Ecology* 41: 305-314.

Andrews, D.G. (1964). Birds in Ireland 1960-62. *British Birds* 57 (Issue 1): 1-10.

Andrews, A. (1990). Fragmentation of habitat by roads and utility corridors: a review. *Australian Zoologist* 26: 130-141.

Arroyo, B., Leckie, F. and Redpath, S. (2006). Habitat use and range management on priority areas for hen harriers: final report. Report to Scottish Natural Heritage. 57pp. Edinburgh, UK.

Arroyo, B., Amar, A., Leckie, F., Buchanan, G. M., Wilson, J. and Redpath, S. (2009). Hunting habitat selection by hen Harriers on moorland: Implications for conservation management. *Biological Conservation* 142: 586-596.

Arroyo, B., Leckie, F., Amar, A., McCluskie, A. and Redpath, S. (2014). Ranging behaviour of Hen Harriers breeding in Special Protection Areas in Scotland. *Bird Study* 61: 48-55.

Balmer, D., Gillings, S., Caffrey, B., Swan, B., Downie, I. and Fuller, R. (2013). *Birds Atlas 2007-11: The breeding and wintering birds of Britain and Ireland*. British Trust for Ornithology.

Band, W., Madders, M. and Whitfield, D. P. (2007). Developing field and analytical methods to assess avian collision risk at wind farms. In de Lucas, M., Hanss, G. and Ferrer, M. (eds). Birds and wind farms: Risk assessment and mitigation. pp Quercus.

Bannerman, D.A. and Lodge, G.E. (1956). *The Birds of the British Isles*, Volume 5. Oliver and Boyd, Edinburgh.

Barclay, R. M. R., Baerwald, E. F. and Gruver, J. C. (2007). Variation in bat and bird fatalities at wind energy facilities: assessing the effects of rotor size and tower height. *Canadian Journal of Zoology* 85: 381–387.

Barclay, C. (2010). Wind Farms - Distance from housing. Standard Note: SN/SC/5221: Science and Environment. House of Commons Library November 2010.

Barrios, L. and Rodriguez, A. (2004). Behavioural and environmental correlates of soaring-bird mortality at on-shore wind turbines. *Journal of Applied Ecology* 41: 72-81.

Barton, C., Pollock, C., Norriss, D.W., Nagle, T., Oliver, G.A. and Newton, S. (2006). The second national survey of breeding hen harriers *Circus cyaneus* in Ireland 2005. *Irish Birds* 8: 1-20.

Bellebaum, J., Korner-Nievergelt, F., Dürr, T. Mammen, U. (2013). Wind turbine fatalities approach a level of concern in a raptor population. *Journal for Nature Conservation* 21: 394-400.

Bennett, V. J., Hale, A. M., Karsten, K. B., Gordon, C. E. and Suson, B. J. (2014). Effect of wind turbine proximity on nesting success in shrub-nesting birds. *The American Midland Naturalist* 172: 317-328.

Bevanger, K., Berntsen, F., Clausen, S., Dahl, E. L., Flagstad, Ø., Follestad, A., Halley D., Hanssen, F., Johnsen, L., Lund-Hoel, P., May, R., Nygård, T., Pedersen, H. C., Reitan, O., Røskaft, E., Steinheim, Y., Stokke, B. and Vang, R. (2010). Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway (Bird-Wind). Report on findings 2007-2010. – NINA Report 620: 152 pp. Norwegian Institute for Nature Research, Trondheim.

BirdLife International. (2004). Birds in Europe: population estimates, trends and conservation status. Cambridge, UK. BirdLife International.

BirdLife International (2015). European Red List of Birds. Luxembourg: Office for Official Publications of the European Communities.

Braun, C.E. (1998). Sage Grouse declines in western North America: What are the problems? *Proceedings of the Western Association of State Fish and Wildlife Agencies*. 78:139-156.

Bright, J. A., Langston, R. H. W., J, E. R., Gardner, S., Pearce-Higgins, J. and Wilson, E. (2006). Bird sensitivity map to provide locational guidance for onshore wind farms. A report by the Royal Society for the Protection of Birds, as part of a programme of work jointly funded by the RSPB and Scottish Natural Heritage. *RSPB Report No*. 20. 136pp.

Bright, J. A., Langston, R. H. W., Bullman, R., Evans, R., Gardner, S. and Pearce-Higgins, J. W. (2008a). Map of bird sensitivities to wind farms in Scotland: A tool to aid planning and conservation. *Biological Conservation* 141: 2342-2356.

Bright, J. A., Langston, R. H. W., Pearce-Higgins, J. W., Bullman, R., Evans, R. and Gardner, S. (2008b). Spatial overlap of wind farms on peatland with sensitive areas for birds. *Mires and Peat* 4: 1-12.

Campedelli, T., Londi, G., Cutini, S., Sorace, A. and Tellini Florenzano, G. (2013). Raptor displacement due to the construction of a wind farm: preliminary results after the first 2 years since the construction. *Ethology Ecology and Evolution* 26: 376-391.

Carrete, M., Sánchez-Zapata, J. A., Benítez, J. R., Lobón, M. and Donázar, J. A. (2009). Large scale risk-assessment of wind-farms on population viability of a globally endangered long-lived raptor. *Biological Conservation* 142: 2954-2961.

Carrete, M., Sánchez-Zapata, J.A., Benítez, J.R., Lobón, M., Montoya, F., Donázar, J.A., (2012). Mortality at wind-farms is positively related to large-scale distribution and aggregation in griffon vultures. *Biological Conservation* 145: 102–108.

Clarke, R. and Watson, D. (1990). The Hen Harrier *Circus cyaneus* winter roost survey in Britain and Ireland. *Bird Study* 37: 84-100.

Clarke, R. and Watson, D. (1997). The Hen Harrier Winter Roost Survey. Thirteen winters' data reveal serious declines. Raptor 1996/7, 41-45.

Cole, S. G. and Dahl, E. L. (2013). Compensating white-tailed eagles mortality at the Smøla wind-power plant using electrocution prevention measures. *Wildlife Society Bulletin* 37. 84-93.

Glibert, G., Stanbury, A. and Lewis, L. (2021) Birds of Conservation Concern in Ireland 4: 2020-2026. *Irish Birds*, 43: 1-22.

CRU, (2020). Guidance Notes: Applying for an Authorisation to Construct or Reconstruct a Generating Station. 13pp. Commission for Regulation of Utilities, Dublin, Ireland.

Cramp, S. and Simmons, K.E.L. (1980). *The Birds of the Western Palearctic.* Oxford University Press, Oxford.

Crockford, N. J. (1992). A review of the possible impacts of wind farms on birds and other wildlife. *Report for Countryside Council for Wales and English Nature*, 65 pp.

Cruz-Delgado, F., Wiedenfeld, D. and González, J. A. (2010). Assessing the potential impact of wind turbines on the endangered Galapagos Petrol *Pterodroma phaeopygia* at San Cristbal Island, Galapagos. Biodiversity and Conservation 19.

Currie, F. and Elliott, G. (1997). Forests and birds: a guide to managing forests for rare birds. Cambridge: Forestry Authority and Royal Society for the Protection of Birds.

DAFM (2019a). Agriculture, Forest and Seafood: Climate Change Sectoral Adaptation Plan. Department of Agriculture, Food and the Marine.

DAFM, (2019b). The A to Z of Climate Change and Agriculture. Department of Agriculture, Food and Marine.

Dahl, E. L., Bevanger, K., Nygård, T., Røskaft, E. and Stokke, B. G. (2012). Reduced breeding success in white-tailed eagles at Smøla windfarm, western Norway, is caused by mortality and displacement. *Biological Conservation* 145: 79-85.

Dahl, E. L., May, R., Hoel, P. L., Bevanger, K., Pedersen, H. C., Røskaft, E. and Stokke, B. G. (2013). White-tailed eagles (*Haliaeetus albicilla*) at the Smøla wind-power plant, Central Norway, lack behavioural flight responses to wind turbines. Wildlife Society Bulletin 37: 66-74.

Dáil Éireann (2019). Houses of the Oireachtas, 2019, Committee on Climate Action, 32nd Dáil. *Report of the Joint Committee on Climate Action Climate Change: A Cross Party Consensus for Action.* Dublin, Ireland.

DCCAE, (2015). Ireland's Transition to a Low Carbon Energy Future 2015-2030. Prepared by DCENR. 122 pp.

DCCAE, (2016a). Energy Innovation Ireland: A strategy document produced by the Energy Research Strategy Group for the Minister for Communications, Energy and Natural Resources. 75 pp.

DCCAE, (2016b). Draft Renewable Electricity Policy and Development Framework. Draft strategic environmental assessment scoping report 2016. 80pp.

DCCAE, (2019). Climate Action Plan 2019: To Tackle Climate Breakdown. Government of Ireland.

DCCAE, (2020). National Energy and Climate Plan 2021-2030. Department of Communications, Climate Action and Environment.

DCENR (2009). National Energy Efficiency Action Plan 2009. Department of Communications, Energy and Natural Resources. 158 pp.

DCENR (2011). National Energy Efficiency Action Plan 2011. Department of Communications, Energy and Natural Resources. 99 pp.

DCENR. (2012a). Strategy for renewable energy: 2012-2020. Department of Communications, Energy and Natural Resources. 23pp.

DCENR (2012b). Government Policy Statement on the Strategic Importance of Transmission and Other Energy Infrastructure. Department of Communications, Energy and Natural Resources. 8 pp.

DCENR. (2014a). Green Paper on Energy Policy in Ireland. Department of Communications, Energy and Natural Resources. 76pp.

DCENR. (2014b). National Energy Efficiency Action Plan 2014. Department of Communications, Energy and Natural Resources. 136 pp.

DCENR. (2015). Ireland's Transition to a Low Carbon Energy Future 2015-2030. Department of Communications, Energy and Natural Resources. 122 pp.

DCENR. (2016). Draft renewable electricity policy and development framework. Draft Strategic Environmental Assessment Scoping Report. Department of Communications, Energy and Natural Resources. 80 pp.

DECC (2021) Climate Action Plan 2021: Securing our Energy Future. Government of Ireland.

Del Hoyo, J., Elliot, A., Sargatal, J. (1992). *Handbook of the Birds of the World, vol. 1: Ostrich to Ducks*. Lynx Edicions, Barcelona, Spain.

De Lucas, M., Janss, G. E. and Ferrer, M. (2004). The effects of a wind farm on birds in a migration point: The Strait of Gibraltar*. Biodiversity and Conservation* 13: 395-407.

De Lucas, M., Janss, G. F. E., Whitfield, D. P. and Ferrer, M. (2008). Collision fatality of raptors in wind farms does not depend on raptor abundance. *Journal of Applied Ecology* 45: 1695-1703.

De Lucas, M., Ferrer, M., Bechard, M. J. and Muñoz, A. R. (2012). Griffon vulture mortality at wind farms in southern Spain: Distribution of fatalities and active mitigation measures. *Biological Conservation* 147: 184-189.

Derby, C., Seginak, K., Dahl, A. and Bay, K. (2008). Wildlife Baseline Studies for the Buffalo Ridge II Wind Resource Area Brookings and Deuel Counties, South Dakota. Final Report March 2008 – November 2008. Prepared for: HDR Engineering, Inc. and Iberdrola Renewables by Western EcoSystems Technology, Inc., North Dakota.

Desholm, M. (2006). Wind farm related mortality among avian migrants – a remote sensing study and model analysis. National Environmental Research Institute. 132 pp.

Desholm, M. and Kahlert, J. (2005). Avian collision risk at an offshore wind farm. *Biology Letters* 1: 296-298.

Devereux, C. L., Denny, M. J. H. and Whittingham, M. J. (2008). Minimal effects of wind turbines on the distribution of wintering farmland birds. *Journal of Applied Ecology* 45: 1689-1694.

Dineen, D and Howley, M. (2016). Energy Efficiency in Ireland 2016 Report prepared by Energy Policy Statistical Support Unit on behalf of Sustainable Energy Authority Ireland (SEAI, March 2016).

DoEHLG. (2000). National Climate Change Strategy Ireland. Department of Environment, Heritage and Local Government. 89 pp.

DoEHLG. (2006). Wind energy development guidelines revision. Department of Environment, Heritage and Local Government. 113pp.

DoEHLG. (2007). Ireland National Climate Change Strategy 2007-2012. Department of Environment, Heritage and Local Government, 60 pp.

DoEHLG. (2009). Appropriate Assessment of Plans and Projects in Ireland: Guidance for Planning Authorities. Department of Environment, Heritage and Local Government, 83pp.

DoEHLG. (2010). Appropriate Assessment of Plans and Projects in Ireland. Guidance for Planning Authorities (as revised 2010). Department of Environment, Heritage and Local Government.

DoEHLG, (2011). Updated Appropriate Assessment of Plans and Projects in Ireland: Guidance for Planning Authorities. Department of Environment, Heritage and Local Government, 83pp.

DHPLG, (2018). Guidelines for Planning Authorities and An Bord Pleanála on carrying out Environmental Impact Assessment. 119 pp. Department of Housing, Planning and Local Government, Dublin.

DHPLG, (2019). Draft Revised Wind Energy Development Guidelines December 2019. 215 pp. Department of Housing, Planning and Local Government, Dublin.

Doherty, K. E., Naugle, D. E., Walker, B. L. and Graham, J. M. (2008). Greater sage-grouse winter habitat selection and energy development. *Journal of Wildlife Management* 72: 187-195.

Douglas, D. J. T., Bellamy, P. E. and Pearce-Higgins, J. W. (2011). Changes in the abundance and distribution of upland breeding birds at an operational windfarm *Bird Study* 58: 37-43.

Drewitt, A. L. and Langston, R. H. W. (2006). Assessing the impacts of wind farms on birds *Ibis* 148: 29-42.

Drewitt, A. L. and Langston, R. H. W. (2008). Collision effects of wind-power generators and other obstacles on birds. *Annals of the New York Academy of Sciences* 1134: 233-266.

European Commission (EC), (2001). Assessment of plans and projects significantly affecting Natura 2000 sites. Methodological guidance on the provisions of Article 6(3) and 6(4) of the Habitats Directive 92/43/EEC. Luxembourg. 81 pp.

EC. (2007/2012). Guidance document on Article 6(4) of the 'Habitats Directive' 92/43/EEC. 30pp. Brussels.

EC. (2010). Guidance Document: Wind energy developments and Natura 2000. 116 pp, Brussels.

ECJ, (2004). Landelijke Vereniging tot Behoud van de Waddenzee vs Nederlandse Vereniging tot

Bescherming van Vogels. Case-127/02. European Court of Justice, Judgment of the Court, Luxembourg.

ECJ, (2018). Grace and Sweetman vs An Bord Pleanála. Case-164/17. European Court of Justice, Judgment of the Court, Luxembourg.

EirGrid and SONI (2016). All-Island Generation Capacity Statement 2016-2025, Report prepared by EirGrid and SONI which incorporates the Generation Capacity Statement for Northern Ireland and the Generation Adequacy Report for Ireland.

EPA (2001). Development of Strategic Environmental Assessment (SEA) Methodologies for Plans and Programmes in Ireland (2001-DS-EEP-2/5) Synthesis Report Prepared for the Environmental Protection Agency by ERM Environmental Resources Management Ireland Limited by Scott, P. and Marsden, P.

EPA (2002). Guidelines on the information to be contained in Environmental Impact Statements. 33pp.

EPA (2003). Advice notes on current practice (in the preparation of Environmental Impact Statements). 28pp.

EPA (2004a). Planning and development (Strategic Environmental Assessment) Regulations 2004. S.I. No. 436 of 2004. Dublin Published by the Stationery Office. 45pp.

EPA (2004b). European Communities (Environmental Assessment of certain plans and programmes) Regulations 2004. S.I. No. 435 of 2004. Dublin Published by the Stationery Office. 23pp.

EPA, (2012). Environmental Protection Agency. (2012). Irish Corine Land Cover 2012 National vegetation mapping programme.

Erickson, W. P., Johnson, G. D., Strickland, M. D., Young Jr, D. P., Sernka, K. J. and Good, R. E. (2001). Avian collisions with wind turbines: a summary of existing studies and comparisons to other sources of avian collision mortality in the United States. National Wind Coordinating Committee (NWCC) Resource Document.

Etheridge, B. and Summers, R. W. (2006). Movements of British Hen Harriers *Circus cyaneus* outside the breeding season. *Ringing and Migration*, 23: 6–14.

Etherington, G.J. and Mobley, J.A. (2016). Molecular phylogeny, morphology and life-history comparisons within *Circus cyaneus* reveal the presence of two distinct evolutionary lineages. *Avian Research* 7: 17. doi: 10.1186/s40657-016-0052-3.

EU (2011). Guidance Document. Wind Energy Developments and Natura 2000. Report prepared by the European Union. 116 pp.

European Environment Agency (2018). List of Pressures and Threats - corresponding measures from 2007-2013 reporting. EIONET Central Data Repository: Reference Portal for Reporting under Article 12 of the Birds Directive.

European Commission, (2019). Communication from the Commission: The European Green Deal. COM (2019) 640 final. Brussels.

European Commission, (2020a). Communication from the Commission: Powering a climate-neutral economy: An EU Strategy for Energy System Integration. COM/2020/299 final. Brussels.

European Commission, (2020b). Commission Notice: Guidance document on wind energy developments and EU nature legislation. C(2020) 7730 final. 181 pp. Brussels.

Farfán, M. A., Vargas, J. M., Duarte, J. and Real, R. (2009). What is the impact of wind farms on birds? A case study in southern Spain. *Biodiversity and Conservation* 18: 3743-3758.

Fennelly, R. (2015). A review of bird strike mortality at Irish onshore windfarms. In Practice*: Bulletin of the Chartered Institute of Ecology and Environmental Management 88* (June 2015): 24-28.

Fernández-Bellon, D., Irwin, S., Wilson, M. and O'Halloran, J. (2015). Reproductive output of Hen Harriers *Circus cyaneus* in relation to wind turbine proximity. *Irish Birds*. 10: 143-150.

Fernández-Bellon, D., Wilson, M.W., Irwin, S. and O'Halloran, J., (2019.) Effects of development of wind energy and associated changes in land use on bird densities in upland areas. *Conservation Biology*, 33(2), pp.413-422.

Ferrer, M., de Lucas, M., Janss, G. F. E., Casado, E., Muños, A. R., Bechard, M. J. and Calabuig, C. (2012). Weak relationship between risk assessment studies and recorded mortality in wind farms. Journal of Applied Ecology. 49: 38-46.

Fielding, A.H., Whitfield, D.P. and Mcleod, D.R.A. (2006). Spatial association as an indicator of the potential for future interactions between wind energy developments and golden eagles *Aquila chrysaetos* in Scotland. Biological Conservation 131: 359-369.

Fielding, A.H. and Haworth, P.F. (2010). Golden eagles and wind farms. A report created under an SNH Call-of-Contract arrangement 56 pp.

Fijn, R.C., Krijgsveld, K.L., Tijsen, W., Prinsen, H.A.M. and Dirksen, S. (2012). Habitat use, disturbance and collision risks for Bewick's Swans *Cygnus columbianus bewickii* wintering near a wind farm in the Netherlands. Wildfowl. 62: 97-116.

Follestad, A., Flagstad, Ø., Nygård, T., Reitan, O. and Schulze, J. (2007). Wind Power and Birds at Smøla 2003-2006. Report by Norwegian Institute for Nature Research (NINA). pp 82.

Forest Service. (2011). Forest Service Policy on the Granting of Felling Licences for Wind Farm Development. 6 pp.

Forrest, J., Robinson, C., Hommel, C. and Craib, J. (2011). Flight activity and breeding success of Hen Harrier at Paul's Hill wind farm in north east Scotland. Poster presented at 2011 Conference on Wind Energy and Wildlife Impacts, Trondheim, Norway.

Garvin, J. C., Jennelle, C. S., Drake, D. and Grodsky, S. M. (2011). Response of raptors to a windfarm. *Journal of Applied Ecology* 48: 199-209.

Gibbons, D.W., Reid, J.B. and Chapman, R.A. (1993). *The new atlas of breeding birds in Britain and Ireland: 1988 - 1991*. Poyser, London.

Green, R.E. and Etheridge, B. (1999). Breeding success of the hen harrier in relation to the distribution of grouse moors and the red fox. *Journal of Applied Ecology* 36: 472-483.

Government of Ireland, (2020). Programme for Government: Our Shared Future, 126 pp. Ireland.

Hagen, C.A., Pitman, J.C., Sandercock, B.K., Robel, R.J. and Applegate, R.D. (2007). Age-specific survival and probable causes of mortality in female lesser prairie-chickens. *Journal of Wildlife Management*, **71**, 518–525.

Hagen, C. A., Pitman, J. C., Loughin, T. M., Sandercock, B. K., Robel, R. J. and Applegate, R. D. (2011). Impact of Anthropogenic Features on Habitat Use by Lesser Prairie-Chickens. Pp. 63-75 in Sandercock, B. J., Martin, K. and Segelbacher, G. (editors). Ecology, conservation, and management of grouse. *Studies in Avian Biology (no. 39)* University of California Press, Berkeley, CA.

Hamerstrom, F. (1969). A Harrier population study. Pages 367-83 in J.J. Hickey, editor. *Peregrine falcon populations: their biology and decline*. University of Wisconsin Press, Madison, WI.

Hamilton, S.D., Millstein, D., Bolinger, M., Wiser, R. and Jeong, S. (2020). How does Wind Project Performance Change with Age in the United States? *Joule,* Volume 4: (5), 1004-1020.

Hardey, J., Crick, H., Wernham, C., Riley, H., Etheridge, B. and Thompson, D. (2013). *Raptors: a field guide for surveys and monitoring*. Edinburgh: The Stationery Office.

Hatchett, E. S., Hale, A. M., Bennett, V. J. and Karsten, K. B. (2013). Wind Turbines do not Negatively Affect Nest Success in the Dickcissel (*Spiza americana*). *The Auk* 130: 520-528.

Haworth, P. F. and Fielding, A. H. (2012). A review of the impacts of terrestrial wind farms on breeding and wintering hen harriers. Report prepared for Scottish Natural Heritage. 39pp.

Hayhow, D. B., Eaton, M. A., Bladwell, S., Etheridge, B., Ewing, S. R., Ruddock, M., Saunders, R., Sharpe, C., Sim, I. M. W. and Stevenson, A. (2013). The status of the Hen Harrier, *Circus cyaneus*, in the UK and Isle of Man in 2010. *Bird Study* 60: 446-458.

Herbert, J.G.M., Iniyan, S., Sreevalsan, E. and Rajapandian, S. (2007*).* A review in wind energy technologies. *Renewable and Sustainable Energy Reviews* 11: 1117-1145.

High Court, 2014. Judgment of Ms. Justice Finlay Geoghegan, 25th July, 2014. Eamon Kelly vs An Bord Pleanála. Judicial Review No. 802 2013, Dublin, Ireland.

Hötker, H. (2006). The Impact of Repowering of Wind Farms on Birds and Bats. Michael-Otto Institute within NABU - Research and Education Centre for Wetlands and Bird Protection. Bergenhusen: NABU.

Hötker, H., Thomsen, K. and Jeromin, H. (2006). Impacts of biodiversity of exploitation of renewable energy sources: the example of birds and bats – facts, gaps in knowledge, demands for further research, and ornithological guidelines for the development of renewable energy exploitation. Bergenhusen: Michael-Otto-Institut im NABU.

Hull, C. L., Stark, E. M., Peruzzo, S. and Sims, C. C. (2013). Avian collisions at two wind farms in Tasmania. Australia: taxonomic and ecological characteristics of colliders versus non-colliders. *New Zealand Journal of Zoology* 40: 47-62.

Humphreys, E. M., Cook, A. S. C. P. and Burton, N. H. K. (2015). Collision, Displacement and Barrier Effect Concept Note. *BTO Research Report* No. 669. 37 pp.

Hunt, G. (2002). Golden eagles in a perilous landscape: Predicting the effects of mitigation for wind turbine blade-strike mortality. Santa Cruz: California Energy Commission. Public Interest Energy Research (PIER) Program, Contract Number 500-97-4033, P500-02-043F 72 pp.

Irwin, S., Wilson, M. W., O'Donoghue, B., O'Mahony, B., Kelly, T. C. and O'Halloran, J. (2012). Optimum scenarios for Hen Harrier conservation in Ireland. Report to the Dept. of Agriculture, Food and the Marine. 47pp.

International Energy Association (2015). IEA WIND: 2014 Annual Report. Executive Committee of the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems of the International Energy Agency. 200pp.

IWEA (2008). Wind Energy Development Best Practice Guidelines. Irish Wind Energy Association. 72pp.

IWEA (2012). Best practice guidelines for the Irish Wind Energy Industry. 87pp. Irish Wind Energy Association.

IWEA (2020). More Power to You: A Guide to Repowering in Ireland. 21pp. Irish Wind Energy Association,

Johnson, G. D., Erickson, W. P., Strickland, M. D., Shepherd, M. F. and Shepherd, D. A. (2000). Avian monitoring studies at the Buffalo Ridge, Minnesota wind resource area: results of a 4-year study. Prepared for Northern States Power Company by WEST Inc. Wyoming.

Johnson, G. D., Erickson, W. P., Strickland, M. D., Good, R. E. and Becker, P. (2001). Avian and bat mortality associated with the initial phase of the Foote Creek Rim Windpower Project, Carbon County, Wyoming. Technical Report prepared by WEST, Inc. 32pp.

Katzner, T. E., Brandes, D., Miller, T., Lanzone, M., Maisonneuve, C., Tremblay, J. A., Mulvihill, R. and Merovich, G. T. (2012). Topography drives migratory flight altitude of golden eagles: implications for on-shore wind energy development. *Journal of Applied Ecology* 49: 1178-1186.

Katzner, E. T., Turk, P. J., Duerr, A. E., Miller, T. A., Lanzone, M. J., Cooper, J. L., Brandes, D., Tremblay, J. A. and Lemaître, J. (2015). Use of multiple modes of flight subsidy by a soaring terrestrial bird, the golden eagle *Aquila chrysaetos*, when on migration. *Journal of the Royal Society Interface*. DOI: 10.1098/rsif.2015.0530.

Katzner, T. E., Nelson, D. M., Braham, M. A., Doyle, J. M., Fernandez, N. B., Duerr, A. E., Bloom, P. H., Fitzpatrick, M. C., Miller, T. A., Culver, R. C. E., Braswell, L. and DeWoody, J. A. (2016). Golden Eagle fatalities and the continental-scale consequences of local wind-energy generation. *Conservation Biology*. DOI: 10.1111/cobi. 12836.

Kennedy, P.G., Ruttledge, R.F. and Scroope, C.F. (1954). *The Birds of Ireland*. Oliver and Boyd, London.

Kingsley, A. and Whittam, B. (2005). Wind turbines and birds a background review for environmental assessment. A report prepared for Environment Canada / Canadian Wildlife Service.

Kitzing, L., Jensen, M. K., Telsnig, T., and Lantz, E. (2020). Multifaceted drivers for onshore wind energy repowering and their implications for energy transition. *Nature Energy*. 5, pp 1012-1021.

Kunz, T. H., Arnett, E. B., Cooper, B. M., Erickson, W. P., Larkin, R. P., Mabee, T., Morrison, M. L., Strickland, M. D. and Szewczak, J. M. (2007). Assessing impacts of wind-energy development on nocturnally active birds and bats: A guidance document. *The Journal of Wildlife Management* 71: 2449-2486.

Lacal Arantegui, R., Uihlein, A. and Yusta Loyo, J., (2020). Technology effects in repowering wind turbines, WIND ENERGY, ISSN 1095-4244 (online), 23 (3), p. 660-675.

Lammers, W. M. and Collopy, M. W. (2005). Effectiveness of avian predator perch deterrents on electric transmission lines. *The Journal of Wildlife Management* 2752-2758.

Langston, R., and Pullan, J. (2003). Windfarms and birds: an analysis of the effects of wind farms on birds, and guidance on environmental assessment criteria and site selection issues. Report T-PVS/Inf (2003) 12, by BirdLife International to the Council of Europe, Bern Convention on the Conservation of European Wildlife and Natural habitats. RSPB/BirdLife in the UK.

Lantz, E., Leventhal, M. and Baring-Gould, I. (2013). Wind Power Project Repowering: Financial Feasibility, Decision Drivers, and Supply Chain Effects. Technical Report NREL/TP-6A20-60535 December 2013.

Larsen, J. K. and Guillemette, M. (2007). Effects of wind turbines on light behaviour of wintering common eiders: implications for habitat use and collision risk. *Journal of Applied Ecology* 44: 516-522.

Larsen, J. K. and Madsen, J. (2000) Effects of wind turbines and other physical elements on field utilization by pink-footed geese (*Anser brachyrhynchus*): A landscape perspective. *Landscape Ecology*. 15: 755. doi: 10.1023/A:1008127702944.

Lawrence, E. S., Painter, S. and Little, B. (2007). Responses of birds to the wind farm at Blythe harbour, Northumberland, UK. In De Lucas, M., Janss, G. and Ferrer, M. (eds). Birds and wind farms: Risk assessment and mitigation. pp 47-69. Quercus.

Lekuona, J.M and Ursúa, C. (2007). Avian mortality in wind power plants of Navarra (Northern Spain). In: De Lucas M, Janss GFE, Ferrer M (eds) Birds and wind farms: risk assessment and mitigation. Editorial Quercus, Madrid, pp 177–192.

Lydon, K., and Smith, G. (2014). CORINE Landcover 2012 Ireland. Final Report. Environmental Protection Agency, Johnstown Castle, Co. Wexford, Ireland, 55 pp.

Mabey, S. and Paul, E. (2007). Critical Literature Review Impact of Wind Energy and Related Human Activities on Grassland and Shrub-Steppe Birds. Report prepared for the National Wind Coordinating Collaborative by the Ornithological Council. The National Wind Coordinating Collaborative, Resolve, Inc., Washington, D.C. 183 pp.

Madden, B. and Porter, B. (2007). Do wind turbines displace Hen Harriers *Circus cyaneus* from foraging habitat? Preliminary results of a case study at the Derrybrien wind farm, County Galway. *Irish Birds* 8: 231-236.

Madders, M. (2000). Habitat selection and foraging success of Hen Harriers *Circus cyaneus* in west Scotland. *Bird Study* 47: 32-40.

Madders, M. (2002). Method statement for Vantage Point watches. In: Survey methods to assess windfarm impacts on upland bird communities. Scottish Natural Heritage.

Madders, M. (2003). Hen Harrier *Circus cyaneus* foraging activity in relation to habitat and prey. *Bird Study* 50: 55-60.

Madders, M. (2004). The ecology of hen harriers in Scotland in relation to windfarms. Report on Penbreck and Carmacoup proposed windfarm.

Madders, M. and Whitfield, D. P. (2006). Upland raptors and the assessment of wind farm impacts. *Ibis* 148: 43-56.

Masden, E. A., Haydon, D. T., Fox, A. D., Furness, R. W., Bullman, R. and Desholm, M. (2009). Barriers to movement: impacts of wind farms on migrating birds. – ICES Journal of Marine Science 66: 746–753.

Madsen, J. and Boertmann, D. (2008). Animal behavioural adaptation to changing landscapes: spring-staging geese habituate to wind farms. *Landscape Ecology* 23: 1007-1011.

Mañosa, S. (2001). Strategies to identify dangerous electricity pylons for birds. *Biodiversity and Conservation* 10: 1997-2012.

Marques, A. T., Batalha, H., Rodrigues, S., Costa, H., Pereira, M. J. R., Fonseca, C., Mascarenhas, M. and Bemardino, J. (2014). Understanding bird collisions at wind farms: An updated review on the causes and possible mitigation strategies. *Biological Conservation* 179: 40-52.

Martin, G. R. and Shaw, J. M. (2010). Bird collision with power lines: Failing to see the way ahead? *Biological Conservation* 143:2695-2702.

Martinez-Abraín, A., Tavecchia, G., Regan, H.M., Jimenez, J., Surroca, M. and Oro, D. (2012). Effects of wind farms and food scarcity on a large scavenging bird species following an epidemic of bovine spongiform encephalopathy. *Journal of Applied Ecology* 49: 109-117.

Martínez-Abraín, A., Crespo, J., Berdugo, M., Gutiérrez, L., Lafuente, A., Mañas, A. and de Miguel, J.M. (2013). Causes of human impact to protected vertebrate wildlife parallel long-term socio-economical changes in Spain. *Animal Conservation* 16: 286-294.

Masden, E.A., Haydon, D.T., Fox, A.D., Furness, R.W., Bu llman, R. and Desholm, M. (2009). Barriers to moveme nt: impacts of wind farms on migrating birds. *Ices Jou rnal of Marine Science* 66: 746-753.

McGuinness, S., Muldoon, C., Tierney, N., Cummins, S., Murray, A., Egan, S. and Crowe, O. (2015). Bird sensitivity mapping for wind energy developments and associated infrastructure in the Republic of Ireland. BirdWatch Ireland, Kilcoole.

McMillan, R.L. (2014). Hen harriers on Skye, 2000–12: nest failures and predation. *Scottish Birds* 34: 30-39.

Minderman, J., Pendlebury, C. J., Pearce-Higgins, J. W. and Park, K. J. (2012). Experimental Evidence for the Effect of Small Wind Turbine Proximity and Operation on Bird and Bat Activity. *PLoS ONE*. Volume 7: e41177. Doi:10.1371/journal.pone.0041177.

Moran, P. and Wilson-Parr, R. (2015). Hen Harrier Special Protection Area (SPA) Habitat Mapping Project 2014. Irish Wildlife Manuals, No. 83. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht.

National Renewable Energy Laboratory (2013). Technical Report NREL/TP-6A20-60535 December 2013 "Wind Power Project Repowering: Financial Feasibility, Decision Drivers, and Supply Chain Effects" Eric Lantz, Michael Leventhal, and Ian Baring-Gould.

Norriss, D. W., Marsh, J., McMahon, D. and Oliver, G. A. (2002). A national survey of breeding Hen Harriers *Circus cyaneus* in Ireland 1998-2000. *Irish Birds* 7: 1-10.

Northrup, J.M. and Wittemayer, G. (2016). Characterising the impacts of emerging energy development on wildlife, with an eye towards mitigation. *Ecology Letters* 16: 112–125.

NPWS (2002). Recommended methodology for assessment of impacts of proposed windfarms on breeding hen harrier within the known range of the species in Ireland. Report prepared by NPWS. 3pp.

NPWS (2007). Rationale for the selection of SPAs for breeding Hen Harrier in Ireland. Information Note. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht.

NPWS. (2013). Birds Directive Article 12 Species Reports. EIONET.

NPWS (2015a). Hen Harrier Conservation and the Forestry Sector in Ireland. Report prepared by NPWS to inform the Hen Harrier Threat Response Plan (HHTRP) Version 3.2. 1-50.

NPWS (2015b). Hen Harrier Conservation and the Agricultural Sector in Ireland. Report prepared by NPWS to inform the Hen Harrier Threat Response Plan (HHTRP).

NPWS (2016). Review Turbine Database. Dublin, Ireland.

Nygård, T., Bevanger, K., Dahl, L., Flagstad, Ø., Follestad, A., Hoel, P. L., May, R. and Reltan, O. (2010). A study of White-tailed Eagle *Haliaeetus albicilla* movements and mortality at a wind farm in Norway. *BOU Proceedings – Climate Change and Birds* 1-4.

Obermeyer, B., Manes, R., Kiesecker, J., Fargione, J. and Sochi, K. (2011). Development by Design: Mitigating Wind Development's Impacts on Wildlife in Kansas. *PLoS One* 6: e2669. doi: 10.1371/journal.pone.0026698.

O'Donoghue, B.G. (2004). The Hen Harrier in Ireland. Master's Thesis. National University of Ireland, Dublin.

O'Donoghue, B. G. (2010). The Ecology and Conservation of Hen Harriers (*Circus cyaneus*) in Ireland. PhD Thesis submitted to University College Cork.

O'Donoghue, B., O'Donoghue, T. A. and King, F. (2011). The Hen Harrier in Ireland: conservation issues for the 21st Century. *Biology and Environment: Proceedings of the Royal Irish Academy* 111: 1-11.

O'Donoghue, B. G. (2012). Duhallow Hen Harriers *Circus cyaneus* - from stronghold to just holding on. *Irish Birds* 9: 349-356.

O'Flynn, W. J. (1983). Population changes of the Hen Harrier in Ireland. *Irish Birds* 2: 337-343.

Orlaff, S. and Flannery, A. (1992). Wind turbine effects on avian activity, habitat use, and mortality in Altamont Pass and Solano County Wind Resource Areas 1989-1991. Biosystems Analysis Inc. *California Energy Commission*. 160 pp.

Osborn, J.G. and Shillinger, G.L. (1996). Wind turbines and raptor mortality: risk reduction through the application of GIS and remote sensing technologies. *Bulletin of the Ecological Society of America* 77: 336.

Osborn, R. G., Higgins, K. F., Usgaard, R. E., Dieter, C. D. and Neiger, R. D. (2000). Bird Mortality Associated with Wind Turbines at the Buffalo Ridge Wind Resource Area, Minnesota. *American Midland Naturalist* 143: 31-52.

Osbourne, J. D., Anderson, J. T., and Spurgeon, A. B. (2005). Effects of habitat on small mammal abundance in West Virginia. *Wildlife Society Bulletin*, 33, 814–822.

Pearce-Higgins, J.W., Stephen, L., Langston, R.H.W., Bainbridge, I.P. and Bullman, R. (2009a). The distribution of breeding birds around upland wind farms. *Journal of Applied Ecology* 46: 1323-1331.

Pearce-Higgins, J.W., Grand, M. C., Beale, C.M., Buchanan, G.M. and Sim, I. M. W. (2009b). International importance and drivers of change of upland bird populations. In Bonn, A., Allott, T., Hubacek, K. and Stewart, J. (eds). Drivers of environmental change in the uplands. pp 209-227. Routledge, Abingdon, UK.

Pearce-Higgins, J. W., Stephen, L., Douse, A. and Langston, R. H. W. (2012). Greater impacts of wind farms on bird populations during construction than subsequent operation: results of a multi-site and multi-species analysis. *Journal of Applied Ecology* 49: 386-394.

Percival, S. M. (2003). Birds and wind farms in Ireland: A review of potential issues and impact assessment. *Ecology Consulting*. 25pp.

Petty, S.J. (1998). Ecology and conservation of raptors in forests. *Forestry Commission Bulletin* 118. HMSO, London.

Picozzi, N. (1980). Food, growth, survival and sex ratio of nestling Hen Harriers *Circus cyaneus* in Orkney. *Ornis Scandinavia* 11: 1-11.

Plonczhier, P. and Simms, I. C. (2012). Radar monitoring of migrating pink-footed geese: behavioural responses to offshore wind farm development. *Journal of Applied Ecology*, 49: 1187-1194.

Pruett, C. L., Patten, M. A. and Wolfe, D. H. (2009a). It's not easy being green: wind energy and a declining grassland bird. *Bioscience* 59: 257-262.

Pruett, C. L., Patten, M. A. and Wolfe, D. H. (2009b). Avoidance behaviour by Prairie grouse: implications for development of wind energy. Conservation Biology 23: 1253-1259.

Rasuo, B. and Bengin, A.C. (2010). Optimization of wind farm layout. FME Transactions 38: 107–114.

Redpath, S., Madders, M., Donnelly, E., Anderson, B., Thirgood, S., Martin, A. and McLeod, D. (1998). Nest site selection by Hen Harriers in Scotland. *Bird Study* 45: 51 - 61.

Redpath, S., Amar, A., Madders, M., Leckie, F. and Thirgood, S. (2002a). Hen Harrier foraging success in relation to land use in Scotland. *Animal Conservation* 5: 113-118.

Redpath, S., Arroyo, B., Etheridge, B., Leckie, F., Bouwman, K. and Thirgood, S. (2002b). Temperature and hen harrier productivity: from local mechanisms to geographical patterns. *Ecography* 25: 533-540.

Robson, P. (2011). Hen Harrier activity at Cruach Mhor windfarm: Review of monitoring data 2001 – 2011. ScottishPower Renewables. 13pp.

RSPB (2012). Two hen harriers killed at Perthshire windfarm. RSPB Press Release December 2012.

Ruddock, M. and Reid, N. (2010) Review of windfarms and their impact on biodiversity: Guidance for developments in Northern Ireland. Report by the Natural Heritage Research Partnership, Quercus for the Northern Ireland Environment Agency, Northern Ireland, UK.

Ruddock, M. and Whitfield, D. (2007). A review of disturbance distances in selected bird species. A report from Natural Research (Projects) Ltd to Scottish Natural Heritage. 181pp.

Ruddock, M., Madders, M., McEvoy, P. and Montgomery, I., (2008). Ecological and breeding parameters of the hen harrier (*Circus cyaneus*) with particular reference to the Antrim Hills and Slieve Beagh-Mullaghfad-Lisnaskea SPAs*. An unpublished Quercus report to Environment and Heritage Service*.

Ruddock, M., Dunlop, B. J., O'Toole, L., Mee, A. and Nagle, T. (2012). Republic of Ireland Hen Harrier Survey 2010. Irish Wildlife Manual No. 59. National

Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht. 90pp.

Ruddock, M., Mee, A., Lusby, J., Nagle, A., O'Neill, S. and O'Toole, L. (2016a). The 2015 National Survey of Breeding Hen Harriers in Ireland. Irish Wildlife Manuals, No. 93. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht.

Ruddock, M., Mee, A., Lusby, J., Nagle, A., O'Neill, S. and O'Toole, L. (2016b). 2015 Irish Hen Harrier survey post hoc analysis unpublished report prepared for National Parks and Wildlife Service of the Department of Arts, Heritage and the Gaeltacht.

Salo, P., Banks, P.B., Dickman, C.R. and Korpimäki, E. (2010). Predator manipulation experiments: impacts on populations of terrestrial vertebrate prey. *Ecological Monographs* 80: 531-546.

Sarkar, A. and Behera, K. (2012). Wind turbine blade efficiency and power calculation with electrical analogy. *International Journal of Scientific and Research Publications* 2: 2250-3153.

Scharf, W.C. and Balfour, E. (1971). Growth and development of nestling Hen Harriers. *Ibis* 113: 323-329.

Schaub, T., Klaassen, R.H., Bouten, W., Schlaich, A.E. and Koks, B.J. (2020). Collision risk of Montagu's Harriers *Circus pygargus* with wind turbines derived from high-resolution GPS tracking. *Ibis*, 162: 520-534.

Schmidt, K.A. and Ostfeld, R.S. (2003). Songbird populations in fluctuating environments: predator responses to pulsed resources. Ecology 84: 406-415.
Scott, D. (1995). Hen Harriers in County Wicklow, 1961. Irish East Coast Bird Report 1995.

Scott, D., Clarke, R. and Shawyer, C.R. (1991). Hen harriers breeding in a tree nest. *Irish Birds* 4: 413–417.

Scott, D. and McHaffie, P. (2008). Hen Harrier *Circus cyaneus* killed at windfarm site in County Antrim. *Irish Birds* 8: 436-437.

SEAI, (2011). Wind Energy Roadmap to 2050. Sustainable Energy Authority of Ireland. 10pp.

SEAI, (2013a). Methodology for Local Authority Renewable Energy Strategies. 72 pp. Sustainable Energy Authority of Ireland.

SEAI, (2013b). Remodelling the Irish national onshore and offshore wind atlas. A report prepared by the Met Office by Standen, J., Wilson, C. and Vosper, S. for the Sustainable Energy Authority of Ireland.

SEAI, (2016a). Annual Report 2016 on Public Sector Energy Efficiency Performance. Sustainable Energy Authority of Ireland. 117pp.

SEAI, (2016b). Ireland's Energy Targets: Progress, Ambition and Impacts. Summary for Policy-Makers. Sustainable Energy Authority of Ireland. 30pp.

SEAI (2018). National Energy Projections to 2030. Understanding Ireland's Energy Transition. Sustainable Energy Authority of Ireland, Dublin. 28 pp.

SEAI, (2020). Renewable Energy in Ireland. 2020 Report. 48pp. Sustainable Energy Authority of Ireland.

Sharrock, J.T.R. (1976). *The Atlas of Breeding Birds in Britain and Ireland.* Poyser, Berkhamsted.

Sim, I.M.W., Gibbons, D.W., Bainbridge, I.P. and Mattingley, W.A. (2001). Status of the Hen Harrier *Circus cyaneus* in the UK and the Isle of Man in 1998. *Bird Study* 48: 341-353.

Sim, I.M.W., Dillon, I.A., Eaton, M.A., Etheridge, B., Lindley, P., Riley, H., Saunders, R., Sharpe, C. and Tickner, M. (2007). Status of the Hen Harrier *Circus cyaneus* in the UK and Isle of Man in 2004, and a comparison with the 1988/89 and 1998 surveys. *Bird Study* 54: 256-267.

Simmons, R.E. (2000). *Harriers of the World: Their Behaviour and Ecology.* Oxford University Press, Oxford.

Skagen, S.K., Stanley, T.R., and Dillon, M.B. (1999). Do mammalian nest predators follow human scent trails in the shortgrass prairie? *The Wilson Bulletin* 415-420.

Smallie, J. and Virani, M.Z. (2010). A preliminary assessment of the potential risks from electrical infrastructure to large birds in Kenya. *Scopus* 30: 32–39.

Smallwood, K.S. (2013). Comparing bird and bat fatality-rate estimates among North American wind-energy projects. *Wildlife Society Bulletin* 37: 19-33.

Smallwood, K.S. and Karas, B. (2008). Avian and bat fatality rates at old-generation and repowered wind turbines in California. *The Journal of Wildlife Management* 73: 1062-1071.

Smallwood, K.S., Rugge, L. and Morrison, M.L. (2009). Influence of behaviour on bird mortality in wind energy developments. *Journal of Wildlife Management* 73: 1082-1098.

Smallwood, K.S. and Thelander, C.G. (2004). Developing methods to reduce bird mortality in the Altamont Pass Wind Resource Area. Final Report by Bio Resource Consultants to the California Energy Commission, Public Interest Energy Research-Environmental Area, Contract No. 500-01-019. 363pp.

SNH, (2000). Windfarms and birds: calculating a theoretical collision risk assuming no avoiding action. Scottish Natural Heritage.

SNH, (2006). Assessing significance of impacts from onshore windfarms on birds outwith designated areas. July 2006. Scottish Natural Heritage.

SNH, (2011). Guidance on assessing connectivity with Special Protection Areas (SPAs). Scottish Natural Heritage.

SNH, (2014). Repowering onshore wind farms: bird survey requirements. November 2014. 3pp. Scottish Natural Heritage

SNH, (2016). Wind farm proposals on afforested sites – advice on reducing suitability for hen harrier, merlin and short-eared owl. Scottish Natural Heritage.

SPR (2009). Cruach Mhor: Ornithological Monitoring Results 2001-2009. Unpublished report by ScottishPower Renewables.

Stevens, T. K., Hale, A. M., Karsten, K. B. and Bennett, V. J. (2013). An analysis of displacement from wind turbines in a wintering grassland bird community. *Biodiversity and Conservation* 22: 1755-1767.

Stewart, G.B., Pullin, A.S. and Coles, C.F. (2005). Effects of wind turbines on bird abundance. CEE review 04-002 (SR4). Collaboration for Environmental Evidence.

Stewart, G.B., Pullin, A.S. and Coles, C.F. (2007). Poor evidence-base for assessment of windfarm impacts on birds. *Environmental Conservation* 34: 1-11.

Sugimoto, H. and Matsuda, H. (2011). Collision risk of White-fronted geese with wind turbines. *Ornithological Science* 10:61-71.

Supreme Court, (2016). Grace and Sweetman v An Bord Pleanála and ESB Wind Development Ltd. Supreme Court Ref: S:AP:IE:2016:000002. Ireland.

Tellería, J. (2009a). Wind power plants and the conservation of birds and bats in Spain: a geographical assessment. *Biodiversity and Conservation* 18: 1781-1791.

Tellería, J. L. (2009b). Overlap between wind power plants and Griffon Vultures *Gyps fulvus* in Spain. *Bird Study* 56: 268-271.

Thaxter, C.B., Ross-Smith, V.H., Bouton, W., Clark, N.A., Conway, G.J., Rehfisch, M.M. and Burton, N.H.K. (2015). Seabird-wind farm interactions during the breeding season vary within and between years: A case study of lesser black-backed gull *Larus fuscus* in the UK. *Biological Conservation* 186: 347-358.

Thirgood, S., Redpath, S. and Graham, I. M. (2003). What determines the foraging distribution of raptors on heather moorland? *Oikos* 100: 15-24.

Thompson, W. (1849). *The Natural History of Ireland, Volume 1.* Bohn, London.

Tierney, N., Murray, A., Cummins, S., Egan, S. and Lauder, A. (2012). Bird Sensitivity Map for Ireland: a tool to aid planning and conservation in relation to Wind energy. 62 pp.

Trombulak, S. C. and Frissell, C. A. (2000). Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. *Conservation Biology* 14: 18–30.

Tryjanowski, P., Sparks, T.H., Jerzak, L., Rosin, Z.M. and Skórka, P. (2013). A paradox for conservation: electricity pylons may benefit avian diversity in intensive farmland. *Conservation Letters* 7: 34-40.

Usgaard, R.; Naugle, D.; Osborn, R.; Higgins, K. (1997). Effects of wind turbines on nesting raptors at Buffalo Ridge in Southwestern Minnesota. *Proceedings of the South Dakota Academy of Science* 76: 113-117.

Ussher, R.J. and Warren, R. (1900). *Birds of Ireland*. Gurney and Jackson, London.

Verma, M., Ahmed, S. and Bhagoria, J. L. (2015). A Review: Repowering of Indian Wind Farms. Department of Mechanical Engineering, Maulana Azad National Institute of Technology, Bhopal, (MP), India.

Walker, D., Mcgrady, M., Mccluskie, A., Madders, M. and Mcleod, D. R. A. (2005). Resident golden eagle ranging behaviour before and after construction of a windfarm in Argyll. *Scottish Birds* 25: 24-40.

Wang, S. and Wang, S. (2015). Impacts of wind energy on environment: a review. *Science Direct* 49: 437-443.

Wang, L., Kolios, A., Luengo, M.M. and Liu, X. (2016). Structural optimisation of wind turbine towers based on finite element analysis and genetic algorithm. *Wind Energy Science Discussions*, doi:10.5194/wes-2016-41, 2016.

Warren, C.R. and Birnie, R.V. (2009). Re-powering Scotland: Wind Farms and the 'Energy or Environment?' Debate. *Scottish Geographical Journal* 125: 97-126.

Watson, D. (1977). *The Hen Harrier*. T and A D Poyser. 312pp.

Watson, A.D. and Dickson, R.C. (1972). Communal roosting of Hen Harriers in south-west Scotland. *Scottish Birds* 7: 24-49.

Welstead, J., Hirst, R., Keogh, D., Robb, G. and Bainsfair, R. (2013). Research and guidance on restoration and decommissioning of onshore wind farms. *Scottish Natural Heritage Commissioned Report No*. 591.

Whelan, C. J., Dilger, M. L., Robson, D., Hallyn, N., and Dilger, S. (1994). Effects of olfactory cues on artificial-nest experiments. *The Auk* 945-952.

Whitfield, D.P., Ruddock, M. and Bullman, R. (2008). Expert opinion as a tool for quantifying bird tolerance to human disturbance. *Biological Conservation* 141: 2708-2717.

Whitfield, D. P. and Madders, M. (2006). A review of the impacts of wind farms on Hen Harriers *Circus cyaneus*. Natural Research Information Note 1 (revised). Banchory, UK: Natural Research Ltd. 32pp.

Wilson, M. W., O'Donoghue, B., O'Mahony, B., Cullen, C., O'Donoghue, T., Oliver, G., Ryan, B., Troake, P., Irwin, S., Kelly, T. C., Rotella, J.J. and O'Halloran, J. (2012). Mismatches between breeding success and habitat preferences in Hen Harrier *Circus cyaneus* breeding in forested landscapes. *Ibis* 154: 578-589.

Wilson, M. W., Irwin, S., Norriss, D. W., Newton, S. F., Collins, K., Kelly, T. C. and O'Halloran, J. (2009). The importance of pre-thicket conifer plantations for nesting Hen Harriers *Circus cyaneus* in Ireland. *Ibis* 151: 332-343.

Wilson, M, Fernández-Bellon, D., Irwin, S. and O'Halloran, J. (2015). The interactions between Hen Harriers and wind turbines. *WINDHARRIER.* Final project report, prepared by School of Biological, Earth and Environmental Sciences, University College Cork, Ireland. PP95.

Wilson, M.W., Fernández-Bellon, D., Irwin, S. and O'Halloran, J. (2016). Hen Harrier *Circus cyaneus* population trends in relation to wind farms. *Bird Study*, Vol. 64, No.1, 20-29.

Winkelman, J. E. (1992). The impact of the Sep Wind park near Oosterbierum, The Netherlands, on birds, 1: collision risk. RIN Report No. 92/2.

Wright, L. J., Ross-Smith, V. H., Massimino, D., Dadam, D., Cook, A. S. C. P., and Burton, N. H. K. (2012). Assessing the risk of offshore wind farm development to migratory birds designated as features of UK Special Protection Areas (and other Annex 1 species). BTO report to the Strategic Ornithological Support Service (SOSS), Thetford.

Zimmerling, J. R., Pomeroy, A. C., d'Entremont, M. V. and Francis, C. M. (2013). Canadian estimate of bird mortality due to collisions and direct habitat loss associated with wind turbine developments. *Avian Conservation and Ecology* 8: 10-22.

Zwart, M. C., Dunn, J. C., McGowan, P. J. K. and Whittingham, M. J. (2016). Wind farm noise suppresses territorial defence behaviour in a songbird. *Behavioural Ecology* 27:101–108.