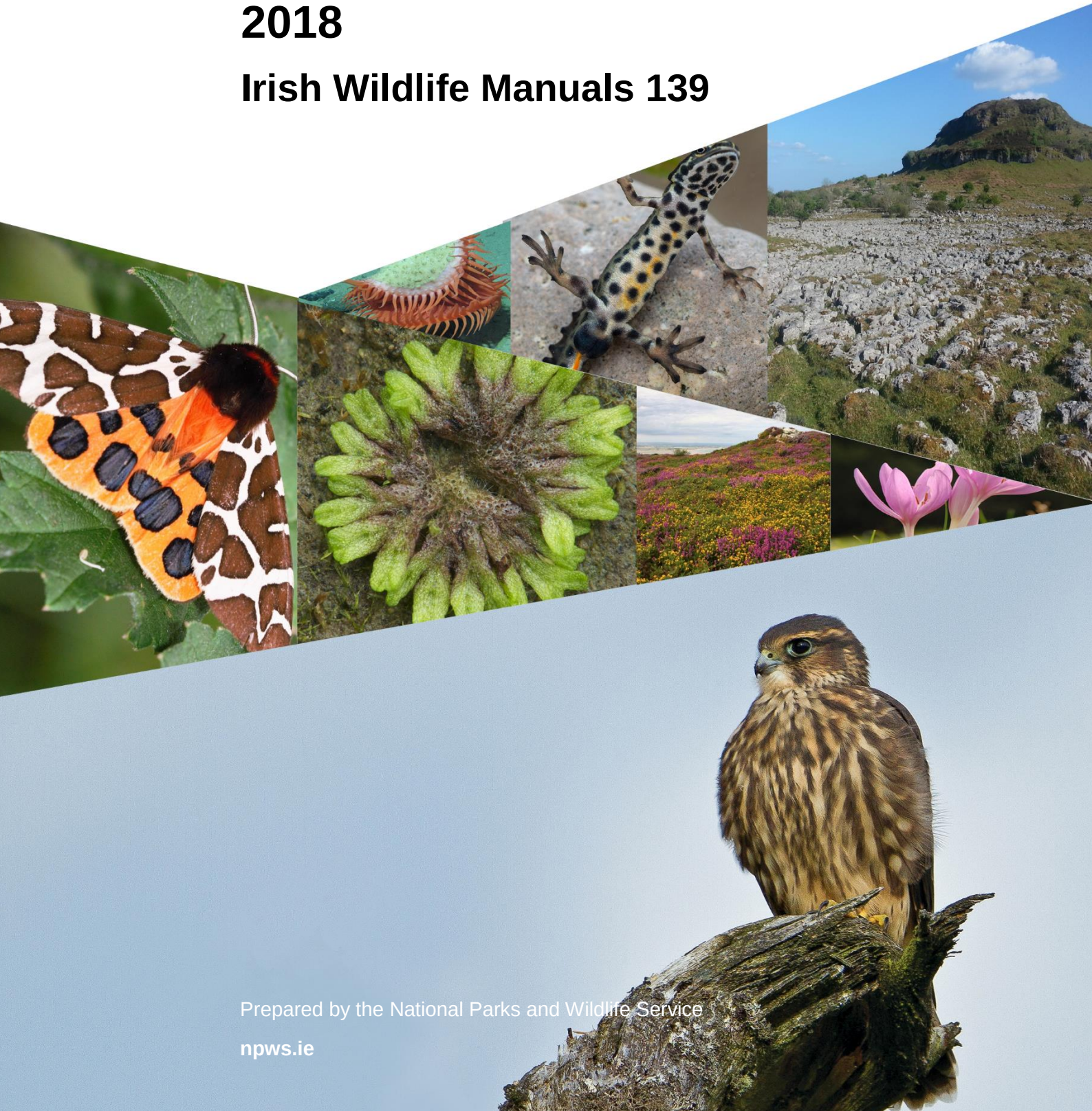
Rialtas na hÉireann
Government of Ireland

Survey of Breeding Merlin in the Special Protection Area Network 2018

Irish Wildlife Manuals 139



Prepared by the National Parks and Wildlife Service

npws.ie

Citation: Lusby, J., O'Brien, I., Lauder, A., Wilson-Parr, R., Breen, D., Cummins, S. & Tierney, D. (2022). Survey of breeding Merlin in the Special Protection Area network 2018. *Irish Wildlife Manuals*, No. 139. National Parks and Wildlife Service, Department of Housing, Local Government and Heritage, Ireland.

Keywords: Merlin, *Falco columbarius*, Special Protection Areas (SPAs), survey, population estimate, breeding densities, breeding performance, habitat selection.

Front cover, small photographs from top row:

A deep water fly trap anemone *Phelliactis* sp., Yvonne Leahy; **Common Newt** *Lissotriton vulgaris,* Brian Nelson; **Limestone pavement**, Bricklieve Mountains, Co. Sligo, Andy Bleasdale; **Garden Tiger** *Arctia caja,* Brian Nelson; **Violet Crystalwort** *Riccia huebeneriana*, Robert Thompson; **Coastal heath**, Howth Head, Co. Dublin, Maurice Eakin; **Meadow Saffron** *Colchicum autumnale*, Lorcan Scott

Bottom photograph: **Merlin** *Falco columbarius*, Neil O'Reilly

Survey of Breeding Merlin in the Special Protection Area Network 2018

Authors, John Lusby[1], Irene O'Brien[2,3], Alan Lauder[3], Ryan Wilson-Parr[3], Dermot Breen[2,3], Sinéad Cummins[2] & David Tierney[2]

[1]BirdWatch Ireland, Bullford Campus, Kilcoole, Co Wicklow

[2]National Parks & Wildlife Service, 90 North King Street, Dublin 7

[3]Irish Raptor Study Group, c/o GET, 12 Ely Place, Dublin, D2

The NPWS Project Officer for this report was: Sinéad Cummins, Sinéad.Cummins@npws.gov.ie

This IWM was edited by Sue Wilson and Domhnall Finch

ISSN 1393 – 6670

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 N7

Contents

Executive Summary

Merlin, *Falco columbarius*, is a species of conservation concern on the island of Ireland, due to a small population and reported declines in its breeding range (Gilbert *et al*., 2021). As an Annex I species on the European Birds Directive 2009/147/EC (European Council Directive 2009/147/EC), Member States are obliged to take appropriate measures to conserve Merlin populations, which includes the designation of Special Protection Areas (SPAs). In Ireland, Merlin is listed as a Species of Conservation Interest (SCI) in seven SPAs. It is a requirement under the Birds Directive that Merlin "shall be the subject of special conservation measures concerning their habitat in order to ensure their survival and reproduction in their area of distribution" and with respect to designated sites.

This is the first survey of breeding Merlin to determine the population size across those sites listed for the species and to allow future changes in the population to be measured. With limited recent evidence of breeding Merlin in Killarney National Park SPA, this SPA was not included in the current survey. The survey was undertaken between April 1 and July 15 2018, with the participation of 60 trained surveyors and over 1,950 hours survey effort to census Merlin populations within the defined survey area of 667.09 km2 across six SPAs. The survey area included 19 survey squares (5 km x 5 km) selected at random in five SPAs and the entire Connemara Bog Complex SPA, which together represent 29% (494.93 km2) of the surface area of the six SPAs. The numbers of confirmed and possible breeding pairs within the area surveyed were used to derive a population estimate for the six breeding Merlin SPAs. Merlin breeding densities, breeding performance and nest site selection was determined to assess the suitability of the SPAs in which Merlin are listed as an SCI for the species and to inform management requirements.

Overall, the total Merlin population for the six breeding Merlin SPAs was estimated to be 28 to 41 pairs extrapolated using the total numbers of confirmed and possible pairs recorded in the area surveyed. A total of ten breeding pairs were confirmed and eight occupied territories in the survey area (667.09 km2), of which eight breeding pairs (80%) and four occupied territories (50%) were within the SPAs, and two breeding pairs (20%) and four territories (50%) were in lands adjacent to the SPAs. Of the 19 survey squares in five SPAs, breeding pairs were confirmed in four squares (21%), six squares were established as occupied (32%) and nine squares were classed as unoccupied (47%). In addition, six breeding pairs and a single occupied territory were confirmed in the Connemara Bog Complex SPA.

Merlin breeding densities in the six SPAs were estimated at 1.6 – 2.4 pairs per 100 km2. These are the first estimates of Merlin breeding densities in the SPAs in which Merlin are listed as an SCI. Although slightly lower than breeding densities previously reported in Ireland, they are comparable to estimates of breeding densities across much of the range of Merlin in Britain but substantially lower than in areas which are considered to be prime habitat for the species. The recorded breeding performance of Merlin in the SPA network was higher than previously reported for most Merlin populations in Ireland and Britain.

To date, this was the most extensive survey of Merlin undertaken in Ireland and demonstrated that a large-scale and strategic survey of Merlin can be implemented using an extensive network of trained surveyors. The sampling strategy employed provides a template for future surveys. The time investment required to effectively census Merlin within the defined survey area highlights the significant challenges with effectively surveying the species. Despite the significant time investment, the time requirements and detection rates of Merlin varied across the SPAs, depending on the landscape conditions and nesting habitat. Based on our findings, we provide recommendations for the future monitoring of the species and the management of these six SPAs for breeding Merlin.

Acknowledgements

We are grateful to Olivia Crowe who provided assistance with mapping and site selection at the early stages and to Claire Lauder who assisted with the development of the online reporting tool. Graham Rebecca of the RSPB provided advice on the survey design and timing, Damian Clarke, National Parks and Wildlife Service provided his input and expertise through the Steering Group and Brian Burke, BirdWatch Ireland assisted with data entry. Thanks to all who submitted information on Merlin within the breeding Merlin SPA network, in particular Shane O'Neill, Fiona Mc Auliffe, Robert Vaughan, and from the Hen Harrier Project. Special thanks to the four survey contractors, Martin Moloney, John Curtin, Geoff Oliver and Rob Wheeldon, who were incredibly dedicated, the level of coverage achieved and knowledge of the species in the breeding Merlin SPA network would not have been possible without their efforts. Particular gratitude to all surveyors and those who participated in the survey workshops. The survey was demanding and required dedication and perseverance. Those who participated in the survey and the survey workshop are listed here, in alphabetical order and we apologise if there are any omissions, which are unintentional: Wesley Atkinson, Penny Bartlett, Lorraine Benson, Sinéad Biggane, Ann Bingham, Sam Birch, Dermot Breen, Killian Brennan, Daniel Buckley, Andrew Butler, Sue Callaghan, John Carey, Helen Carty, Damian Clarke, Cameron Clothworthy, Miriam Crowley, Sinéad Cummins, John Curtin, Eamon Delaney, Ian Edwards, Ann Fitzpatrick, Mags Flaherty, Leonard Floyd, Emma Glanville, Ray Glynn, Paraic Greaney, Colin Heaslip, Mick Hogan, Jackie Hunt, Sarah Ingham, Chris Ingram, Elaine Keegan, Alan Lauder, Denis Lawton, John Lusby, David Lyons, Emer Magee, Fiona McAuliffe, Lee McDaid, Eoin McGreal, David McNamara, David McNicholas, Martin Moloney, Jason Monaghan, Enda Mullen, Gerry Murphy, Jacinta Murphy, Doireann Nichols, David Norriss, Irene O'Brien, Ger O'Donnell, Geoff Oliver, Lorcan O'Toole, Gyr Penn, Brian Reidy, Ann Marie Shaughnessy, Raymond Stephens, Gillian Stewart, Eleanor Sutherland, Dave Suddaby, Rebecca Teesdale, Pat Vaughan, Robert Vaughan, Andrea Webb and Rob Wheeldon. Finally, thanks to all landowners who allowed access to, and across their lands for the purpose of the survey.

1 Introduction

Merlin (*Falco columbarius*) is a small, agile species of falcon and breeds throughout the northern latitudes of Europe, Asia and North America (Sale, 2015). Throughout this circumpolar range, Merlin typically breed in low densities in habitats in or adjacent to open country (i.e. heath and bog) and specialise on small, open-country passerines (Ewing *et al*., 2011; Fernández-Bellon & Lusby, 2011; Sale, 2015). Due to their extensive breeding range and population size, Merlin are listed as Least Concern globally and Secure in Europe, although information on populations vary throughout the region and trends are not known (Staneva & Burfield, 2017). In Ireland, which is at the western and southern limit of its European range, Merlin has a widespread but sporadic distribution across upland habitats and lowland bogs (Balmer *et al*., 2013; Lusby *et al*., 2017). The species is of national conservation concern due to a small population and reported declines in breeding range (Gilbert *et al*., 2021). Article 4 (1) of the European Birds Directive 2009/147/EC (European Council Directive 2009/147/EC) sets out that "Member States shall classify in particular the most suitable territories in number and size as special protection areas for the conservation of these species". As an Annex I species, Ireland has designated seven SPAs for which breeding Merlin is listed as a Special Conservation Interest (SCI). Within these SPAs, Ireland is obliged to take necessary steps to avoid deterioration of natural habitats and disturbance to Merlin, where this disturbance would be significant having regard to the objectives of the Directive. The management of the breeding Merlin SPA network aims to maintain and enhance breeding Merlin populations within, underpinning which, is the requirement (Article 10) to undertake appropriate monitoring to understand the status and trends of Merlin populations and to inform their conservation requirements (BirdWatch Ireland, 2011).

1.1 Status of Merlin in Ireland

Due to its sparse, yet widespread distribution in remote upland areas and discrete breeding behaviour, Merlin is a challenging species to monitor (Ewing *et al*., 2011; Lusby *et al*., 2011). This is reflected in the limited information on Merlin populations in the Irish context. In the absence of a national census or strategic monitoring, a robust estimate of the population size and trends for this species is not available (Lusby *et al*., 2011, 2017). Breeding range declines (*i.e.* changes in recorded 10 km distribution) of 8% and 49% over 20- and 40-year periods have been recorded by the breeding bird atlases (Balmer *et al*., 2013; Gibbons *et al*., 1993; Sharrock, 1976). These recorded range declines have informed the inclusion of Merlin as an Amber-listed Bird of Conservation Concern in Ireland 2020-2026 (Gilbert *et al*., 2021). However, due to difficulties in detecting breeding Merlin, the largely multi-species survey approach employed by bird atlases are unlikely to provide an accurate representation of its national distribution and trends (Lusby *et al*., 2011). Article 12 reporting for the period 2013–2018 (NPWS, 2019), as set out under the Birds Directive, lists the short and long-term trends for the national Merlin population, as well as the short-term trend of populations within the SPA network, for which Merlin are a Species of Conservation Interest (SCI), as 'uncertain'.

1.2 Merlin surveys in Ireland

Although information on population size and population trends of Merlin at a national level are lacking, monitoring of local and regional populations has provided insights on short-term trends and breeding densities in discrete parts of their Irish range. Norriss *et al*. (2010) assessed occupancy rates and the number of breeding pairs in five traditional nesting areas in the east and north-west of Ireland between 1986 and 1992 and showed that Merlin populations remained relatively stable over this period, except for declines in two of the five areas, where these declines were attributed to the loss of heather moorland. This is the only study to date in Ireland which has provided estimates of breeding densities, which ranged from 1.2 to 5.9 pairs per 100 km2 across these five areas (Norriss *et al.*, 2010). McElheron (2005) also

concluded that Merlin populations in the Wicklow Mountains were robust and stable based on monitoring of traditionally occupied territories during the late 1980's and early 1990's. A survey of upland breeding birds in west Galway in 1985 and 1986 included a systematic attempt to locate breeding Merlin, and recorded twelve occupied territories in 1985 and ten occupied territories in 1986, with most pairs nesting on densely vegetated islands on inland lakes in south Connemara (Haworth, 1985; Haworth, 1986). Data from these sources helped to identify suitable areas for Merlin and inform the designation of SPAs for the species. However, with the exception of Connemara (Lusby *et al*., 2017), there has been limited monitoring of Merlin in these SPAs or nationally, with a resulting lack of information on the status and trends of the SPA populations and in the wider countryside. The main limitation to addressing these knowledge gaps has been uncertainty over the reliability of standard survey methods in detecting breeding Merlin and the resources (including surveyor-effort) required to accurately survey the species in Ireland (Lusby *et al*., 2011).

The specific challenges associated with surveying the species in Ireland were highlighted by a Pilot Merlin Survey in 2010, which evaluated best practice survey methodologies to inform the most suitable approach to survey Merlin in Ireland (Lusby *et al*., 2011). This survey compared the efficacy of a range of approaches and observer experience in detecting Merlin. It showed that differences in breeding Merlin behaviour influenced detection rates between territories and these differences could be attributed to landscape features and the availability of perches. As a result, sign searching, which is an established method for determining occupancy of breeding Merlin (Hardey *et al.,* 2009), proved ineffective at certain sites (Lusby *et al*., 2011). Norriss *et al.* (2010) also found that the ability to detect Merlin was dictated by habitat conditions in the vicinity of nest sites and specifically that Merlin avoided plucking prey on open ground in grassland dominated landscapes, and instead used trees at the edge or within forest plantation. Similar to these experiences in Ireland, Little & Davison (1992) found that tree-nesting Merlin in Britain, tended to pluck on branches, making location of tree nests more reliant on sightings than on finding signs and thus harder and more time-consuming. Traditionally Merlin nested on the ground in open heather moorland in Ireland (Hutchinson, 1989), however, from approximately the 1970s onwards there has been a shift to nesting in trees at the edge or within forest plantation (Lusby *et al*., 2017; Norriss *et al*., 2010). Forest nesting Merlin are considered more difficult to find compared with ground nesting pairs (Hardey *et al.,* 2009; Norriss *et al*., 2010), and this may partly explain the constraints in detecting Merlin in Ireland using best practice methodologies compared to other parts of their range.

A similar shift in nest site selection has occurred in parts of Britain, however the majority of the British population are still ground nesting (Hardey *et al*., 2009; Rebecca, 2011). This difference in nest site choice between Britain and Ireland is likely to be related to the greater availability and condition of suitable ground nesting habitats in Britain and may also be influenced by the more extensive afforestation in Britain, in comparison to the pattern of widespread, small-scale afforestation in Ireland (Norriss *et al*., 2010). The effectiveness of survey methods for recording Merlin in Britain and Northern Ireland were assessed using the same approach as was subsequently adopted by the Pilot Merlin Survey in Ireland (Lusby *et al.,* 2011). In contrast to the findings of the Pilot Merlin Survey in Ireland, the trials in the British survey showed that the survey methods used were reliable in detecting breeding Merlin in Britain. Six survey squares (3 km x 3 km) which were surveyed by local raptor fieldworkers, who had previously monitored these same squares, were simultaneously surveyed by contractors without previous experience of Merlin surveys in these areas. Both yielded similar results for all squares (Rebecca & Bainbridge, 1998). Three national surveys of Merlin in Britain and Northern Ireland have been carried out to date, which indicate that the population increased over the ten-year period between the first survey in 1983-84, to the second survey in 1993-94, and thereafter reportedly remained relatively stable until the most recent survey in 2008, which estimated the population at 1,162 breeding pairs (Bibby & Nattrass, 1986; Rebecca & Bainbridge, 1998; Ewing *et al*., 2011). Nevertheless, there have been marked regional declines in Britain and Northern Ireland recorded over this period, the drivers of which, though not fully understood, are likely linked to changes in land use and associated reductions in prey populations (Ewing *et al*., 2011).

1.3 Breeding ecology of Merlin in Ireland

The upland landscape within the breeding range of Merlin in Ireland has been significantly altered over recent decades and this has had a profound effect on the nesting ecology of the species. The substantial decrease in heather cover (Bleasdale, 1998) and overgrazing by sheep in particular in marginal upland areas (Fuller & Gough, 1999) has reduced the availability of Merlin's preferred habitats (Hardey *et al*., 2009), which has coincided with the extensive afforestation of previously open moorland (DAFM, 2018). Likely in response to the long-term degradation of heath and bog habitats and increases in the extent of commercial forest cover across same, the majority of breeding Merlin in Ireland now nest in the abandoned nests of other bird species in forest plantations. In the absence of other available and traditional nesting sites (*i.e.* deep heather), the population may be now largely reliant on this managed commercial resource (Lusby *et al*., 2017). Lusby *et al*. (2017) assessed nest site selection by Merlin using data collated from regional monitoring studies spanning over 30 years (1982-2014). This study confirmed that Merlin now predominantly nest in trees (99.5%), mostly selecting nests at the edge (within 10 m) of mature conifer plantations (80.8%), but having a strong association with, and higher breeding success, where the presence of open habitats suitable for hunting are in close proximity to forest nests. The majority of nest sites in forest plantations were located adjacent to moors and heathland and peat bogs (*i.e.* Land Classes as defined by CORINE LandCover). Merlin showed positive selection for moors and heathland, peat bogs and natural grasslands within breeding territories, and breeding success was positively related to the proportion of these land-uses surrounding nests. Merlin had a breeding success rate of 74% (n = 300), and productivity of 2.1 young per breeding attempt (n = 265) between 1982 and 2014. These estimates of breeding success of Merlin in Ireland are higher than reported for most populations in the UK, although the number of fledged young per successful pair, and overall productivity, were either lower or similar (Newton *et al*., 1978; Roberts & Green, 1983; Bibby & Nattrass, 1986; Newton *et al*., 1986; Meek, 1988; Ellis & Okill, 1990; Rebecca *et al*., 1992; Wright, 1997; Rebecca, 2011). The breeding performance of Merlin in Ireland has remained constant over the past three decades, which suggests that the increase in forest cover over this period has not negatively affected their overall breeding output per se. However, overall, knowledge gaps with respect to the current national population size, national distribution and trends and densities remain (Lusby *et al*., 2017).

1.4 Pressures and threats

Afforestation in Ireland has progressed at one of the highest rates in Europe (Forest Service, 2013), and planting has been primarily concentrated in upland habitats (Wilson *et al*., 2012). Therefore, the upland landscape within the breeding range of Merlin has been rapidly altered, and as a result, Merlin now predominantly occur in landscapes where there is substantial forest cover (Lusby *et al*., 2017). This is a recent and significant ecological shift across their breeding range. Merlin have adapted their nesting behaviour in response to these ecological changes, as planted forest has become the most used nesting habitat (Lusby *et al*., 2017; Norriss *et al*., 2010). As Merlin now predominantly nest in mature conifer plantations, which are within the age range for felling and thinning, they are vulnerable to direct disturbance from forest management operations (Lusby *et al*., 2017). The extent to which breeding Merlin are affected by forestry operations is not known, however it is likely that disturbance incidents are under-recorded due to the lack of information on the distribution of breeding Merlin and the difficulties associated with detecting the species. Since 2020, measures to mitigate the negative effects of forest management operations on Merlin within the breeding Merlin SPA network are applied as a condition to felling licences issued by the Forest Service, where it is deemed the activities may constitute a disturbance to breeding Merlin. However, the effectiveness of these measures and the overall impacts of forest management related disturbances on Merlin are not yet understood.

As well as the potential impacts at the nest site scale, afforestation in upland areas can also affect the availability and suitability of foraging habitats for Merlin at the landscape scale. Merlin are specially adapted to catch avian prey in open and semi-open habitats (*e.g.* open habitats

including unenclosed lands, heather and grass moorland, and semi-open habitats such as boreal forests, as opposed to less open habitats such as dense woodland and plantation forest) (Cade, 1982; Fernandez-Bellon & Lusby, 2011) and select these open habitats in the Irish landscape for hunting. Although Merlin hunt within open forests in boreal areas throughout their range (Sale, 2015), this foraging method is less suited to mature commercial forest plantations in Ireland. Therefore, once suitable nest sites are available, the extent of forest cover may subsequently have a negative effect on Merlin, as has been reported for some Merlin populations in Britain (Newton *et al.*, 1978; Orchel, 1992; Rebecca, 2006). In southwest Scotland, it has been estimated that a minimum of 20 km2 of grass and heather moorland within a mosaic of approximately 60% moorland and 40% forest within 4 km of nests, is necessary for Merlin territories to remain viable (Orchel, 1992). The average proportion of open suitable habitats (peat bog, natural grassland and moors and heathland) within 5 km of breeding territories in Ireland was 59% (Lusby *et al*., 2017), which is slightly lower than estimates at the 4 km scale in southwest Scotland (Orchel, 1992). The average proportion of total forest cover within 5 km of breeding Merlin territories in Ireland was 11% and did not exceed 35% land cover within 5 km of a nest (Lusby *et al*., 2017). Although the extent of forest cover within Irish Merlin territories did not influence breeding performance, based on knowledge of Merlin breeding habitat selection in Ireland and Britain, Lusby *et al*. (2017) suggested that where forest cover is more extensive than observed within the territories (*e.g*. over 35% forest cover with 5 km surrounding nest sites), the suitability for breeding Merlin would be reduced. Although the relationship between Merlin and commercial planted forest is complex, there is sufficient evidence overall for the 2019 Article 12 report (NPWS, 2019) to list afforestation and disturbance from forest management (clear-cutting, removal of all trees) as a moderate influence in broad assessment terms of current pressures and future threats facing the Merlin population in Ireland.

In addition to afforestation, other land-use changes compromising the extent and quality of habitats supporting breeding Merlin include the conversion of upland habitats into agricultural land, which is considered a threat to Merlin populations as detailed in the 2019 Article 12 species report (NPWS, 2019). There has been a major decrease in heather cover over the past century in Ireland (Bleasdale, 1998) due in part to agricultural intensification related to the increase in sheep numbers in marginal upland habitats. Lusby *et al*. (2017) showed that the proportion of suitable open habitats influences nest site selection and breeding success of Merlin in Ireland. Norriss *et al*. (2010) attributed declines in breeding Merlin numbers to the loss of heather moorland in two areas of unenclosed uplands during the late 1980s and early 1990s. In addition, anthropogenic or man-made disturbance activities in the uplands have the potential to cause disturbance to breeding pairs and therefore affect the suitability and quality of these habitats for breeding Merlin. These include peat extraction, (hand-cut and mechanised turf cutting) which was recorded as a potential disturbance activity in areas occupied by Merlin during the Pilot Merlin Survey (Fernandez-Bellon & Lusby, 2010), along with illegal burning and wind energy developments, which are also listed as threats under the 2019 Article 12 reporting 1. These pressures and their potential effects on Merlin populations are informed by an understanding of Merlin ecological requirements in Ireland, however there are remaining knowledge gaps on the factors which influence the species and thus a complete understanding of the pressures and threats which may impact Merlin populations has not yet been achieved (BirdWatch Ireland, 2011).

1.5 Conservation obligations

The EU Birds Directive provides the legislative framework for the conservation of Merlin in Ireland. Under the Birds Directive, Member States are required to maintain the Merlin population (Article 2); preserve, maintain or re-establish a sufficient diversity of areas and habitats (Article 3 & Article 4), which includes the requirement (Article 4(1)) to classify 'the most suitable territories in number and size' as SPAs; encourage necessary research and monitoring work with regard to the objectives above (Article 10) and to report to the European Commission on the progress made with respect to achieving these requirements (Article 12). In order to effectively deliver on these requirements, it is first necessary to address the

knowledge gaps in relation to the ecological and conservation requirements of the species, an essential component of which is establishing baseline data on Merlin populations, to inform the status of the species both within and outside of the breeding Merlin SPAs. This information will also allow future changes in the population to be measured and to inform management requirements and the performance of existing conservation measures including the designation of the breeding Merlin SPA network.

1.6 Objectives

This is the first survey of breeding Merlin within six of the seven SPAs for which they are listed as an SCI. The primary objective of this survey was to determine Merlin occupancy, including the number and location of all breeding attempts within selected survey areas in the targeted SPAs. This will enable Merlin breeding densities to be established, and the number of confirmed and possible breeding pairs within selected survey areas to be extrapolated, to derive a population estimate of the number of breeding Merlin pairs within the breeding Merlin SPAs. It is necessary that the survey design and methods employed are repeatable to allow future changes in the population to be tracked. A key outcome of the survey will be to increase the capacity and surveyor expertise to facilitate enhanced monitoring and future surveys of the species.

The objectives of this survey are therefore, to:

- establish Merlin breeding densities using best practice and repeatable methods to locate all confirmed and possible breeding attempts within selected survey areas;
- quantify Merlin populations within selected survey areas to derive a population estimate for the breeding Merlin SPA network;
- determine the breeding outcomes of confirmed pairs within the breeding Merlin SPA network;
- determine the habitat associations for those breeding attempts within the breeding Merlin SPA network; and,
- identify broad level conservation requirements for breeding Merlin within the SPAs for which Merlin are a SCI

2 Survey design

The survey design is informed by an understanding of breeding Merlin ecology and the challenges associated with surveying the species on a large scale, as well as the surveyor expertise and volunteer base available. A complete survey of the species in the breeding Merlin SPAs is desirable and would provide the most robust population estimate. However, based on the lessons of previous local or regional Merlin surveys (Lusby *et al*., 2011; Norriss *et al*., 2010) and the limitations on the surveyor base, it was not deemed practical to attempt to survey the species over such an extensive area. The survey therefore aimed to sample a representative portion of the breeding Merlin SPAs, to quantify Merlin populations within, and to extrapolate accordingly, to derive a population estimate for the breeding Merlin SPAs.

2.1 Survey areas

Six of the seven SPAs in which Merlin are listed as an SCI were selected for this survey, which are hereafter referred to as the 'breeding Merlin SPAs'. These SPAs were selected based on recent evidence of breeding Merlin in these areas (Balmer *et al*., 2013; Lusby *et al*., 2011, 2017) and the fact that all are known to contain suitable breeding habitat for the species. There is limited recent evidence of breeding Merlin in Killarney National Park SPA (Site Code 004038) (Balmer *et al*., 2013). For this reason, in addition to the constraints on survey coverage, this SPA was not included in the current survey.

To determine the survey area, a representative portion of each of five SPAs was selected, in addition to the complete area of one SPA (Connemara Bog Complex SPA). The size of the survey area selected in each of the five sampled SPAs, was based on the surface area of each individual SPA in order to achieve a minimum survey coverage of 15% in each SPA and 25% of the breeding Merlin SPAs overall. The survey unit was defined as the 5 km x 5 km square based on the Irish National Grid. This survey unit size was selected, based on the Pilot Merlin Survey recommendation that a 3 km x 3 km survey unit may be too small to effectively sample Merlin populations in Ireland (Lusby *et al.,* 2011). The larger survey unit size would also allow comparisons with breeding Merlin densities in other parts of their range. The national Merlin surveys in Britain have used the 10 km x 10 km survey unit (Ewing *et al*., 2011) however this was considered too large for the purposes of this survey and based on the size of individual SPAs. To define the survey area within the five sampled SPAs, the 5 km x 5 km grid was overlaid onto each SPA in QGIS 2.18 (QGIS Development Team, 2018)(as shown in Figure 1) and the survey squares were selected at random and prioritised according to their selection. All 5 km x 5 km survey squares which include lands within the breeding Merlin SPA network were considered for selection, on the basis that potentially suitable breeding habitat for Merlin extends outside the SPA boundary. In certain parts of the breeding Merlin SPAs, open unenclosed lands are within the SPA, whereas adjacent forest plantation is outside the SPA boundary, and breeding Merlin are more likely to use the latter for nesting (Lusby *et al*., 2017). Therefore, only selecting areas within the SPA could increase the risk of overlooking Merlin pairs, which are associated with the SPA, but nesting in bordering habitats. Details of the number of squares selected in each SPA, the size of the survey area and the portion of the survey area within the SPA are shown below in Table 1. The distribution of the sampled survey squares within the five SPAs prioritised for survey coverage are shown below in Figure 1, in addition to the full extent of the Connemara Bog Complex SPA, which collectively were the focus for the Merlin survey and are hereafter referred to as 'the survey area'.

Table 1 The number of survey squares selected and the area relative to the area of each SPA

SPA	Area (km^2)	No. survey squares	Survey area (km^2)	Survey area in the SPA (km^2)	Proportion (%) of SPA
Derryveagh and Glendowan Mountains SPA	314.96	5	125	53.67	17.03
Lough Nillan Bog SPA	41.16	1	25	8.33	20.23
Owenduff/Nephin Complex SPA	257.07	4	100	81.34	31.64
Slieve Aughty Mountains SPA	594.82	5	125	115.73	19.45
Wicklow Mountains SPA	302.07	4	100	43.77	14.49
Connemara Bog Complex SPA	192.09	-	192.09	192.09	100
Total	1702.17	19	667.09	494.93	29

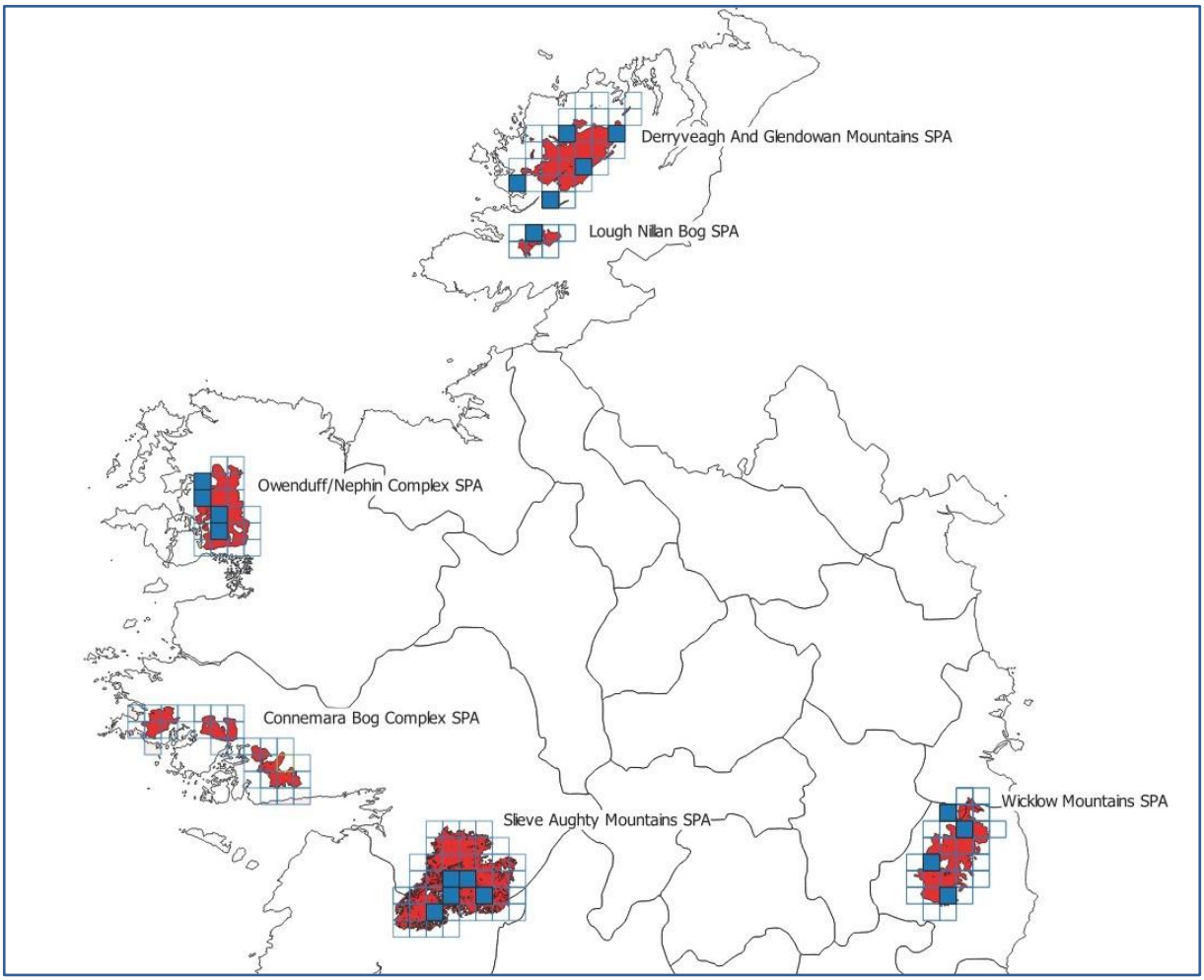


Figure 1 The six SPAs (in red) in which the Merlin survey was undertaken, showing the location of all 5 km x 5 km survey squares which were considered for selection (blue grid) and the survey squares which were prioritised for survey coverage (blue squares).

In addition to the survey area defined above, additional survey effort was focused in two SPAs (Slieve Aughty Mountains SPA and Derryveagh and Glendowan Mountains SPA), targeted to areas where there was suspected or reported evidence of breeding Merlin, in order to obtain information on Merlin occupancy, habitat selection and breeding outcomes. The information

collected in these additional survey areas was not used to derive Merlin breeding densities and population estimates for the SPAs, but rather to supplement data on nesting ecology of the species in the breeding Merlin SPA network.

2.2 Survey coverage and training

Potential surveyors were identified and invited to participate in the survey, which included National Parks and Wildlife Service (NPWS) staff in the relevant areas, BirdWatch Ireland staff and members and Irish Raptor Study Group (IRSG) members. Potential surveyors were identified on the basis of participation in surveys of other raptor species, or experience of bird surveys in upland habitats which required working independently, good bird identification, navigation and recording skills. Other raptor surveys have employed an open recruitment system for surveyors (Ruddock *et al*., 2016), however this was not deemed suitable for the current survey given the experience levels required. In addition, four contract surveyors were assigned to three SPAs (two worked in the Slieve Aughty Mountains SPA and two in Derryveagh and Glendowan Mountains SPA and Lough Nillan Bog SPA) to ensure the required survey coverage was achieved in these SPAs, along with the minimum threshold of 25% coverage for the wider breeding Merlin SPA network.

To ensure that surveyors were familiar with the survey objectives, methods and data recording requirements, and to provide an overview of Merlin ecology and survey techniques, four survey workshops were delivered to accommodate each of the six SPAs in the survey area. Survey workshops are deemed essential when undertaking a specialised survey on Merlin (Lusby *et al.,* 2011), and particularly given that many of the surveyors did not have prior experience of surveying for Merlin albeit had acknowledged skills and experience in other raptor surveys. One workshop was delivered in Gort, in County Galway for surveyors working in both the Slieve Aughty Mountains SPA and the Connemara Bog Complex SPA. One workshop in Glenveagh National Park in County Donegal served those operating in both Derryveagh and Glendowan Mountains SPA and Lough Nillan Bog SPA in Donegal, and one workshop in Ballycroy National Park in County Mayo and the Wicklow Mountains National Park in County Wicklow was organised for surveyors in Owenduff/Nephin SPA and Wicklow Mountains SPA respectively. Workshops consisted of a morning introductory session and an afternoon practical session. The former provided an overview of Merlin ecology, background to the survey and the survey methods; the latter consisted of a field visit to an area of suitable breeding habitat for Merlin with all aspects of the survey methods, techniques and data recording discussed. The workshop presentations were shared with all participants, so that specific components of the survey methods could be revisited as required over the course of the survey season.

Survey squares were allocated to surveyors at the end of each workshop, once surveyors were familiar with the survey requirements. Surveyor teams were formed to cover squares which contained large portions of potentially suitable breeding habitat and individual surveyors were assigned portions of survey squares based on the 1 km x 1 km grid (Irish National Grid). Regional survey co-ordinators[1] were assigned to each SPA and served as the main point of contact for all queries during the survey. They were also responsible for communicating with surveyors throughout the survey, and ensuring the minimum threshold of survey coverage was achieved. Regular communications by the survey co-ordinator (John Lusby) via email, provided updates on the survey, reminders of the survey schedule and timing of required visits, and preliminary findings in order to maintain motivation among surveyors.

Field maps were prepared for each survey square and given to surveyors. These included geo-referenced OSI 1:50,000 maps and aerial photographs for each of the 5 km x 5 km survey squares. The OSI 1:50,000 maps included the 1 km x 1 km grid system (Irish National Grid) were used to record spatially referenced survey data, including the survey area within each

[1] Irene O'Brien in Owenduff/Nephin SPA, Alan Lauder in the Wicklow Mountains SPA, Dermot Breen and John Lusby in the Connemara Bog Complex SPA and John Lusby in the Slieve Aughty Mountains SPA, Lough Nillan Bog SPA and Derryveagh and Glendowan Mountains SPA.

survey square, vantage point locations and view-sheds, and observations of Merlin (Appendix 1). The aerial images showed further detail on habitat features and provided an additional resource for surveyors to assess habitat suitability. Surveyors were provided with an ArcGIS webmap (Appendix 2), which showed the location of all survey squares and SPAs. These maps aided in identifying the location of survey squares relative to others and in the wider landscape, and also helped with navigation and access to and within the survey square. All participants were also provided with the survey methods and recording guidelines, recording form (Appendix 3) and an electronic version of the recording form (excel spreadsheet) for entering the survey data.

3 Methods

3.1 Defining search areas

The search area within each survey square was defined using OSI survey maps and aerial images, in addition to ground-truthing. Areas of unsuitable habitat for breeding Merlin were marked accordingly on OSI survey maps and excluded from further survey effort. All areas of suitable foraging habitat within 300 m of potentially suitable breeding habitat were included in the search area as sign searching, *i.e.* evidence of plucking perches, in suitable foraging habitat, in proximity to potential breeding habitat, can be important in establishing occupancy by Merlin. Areas of suitable foraging habitat located more than 300 m from potential breeding habitats were excluded from the search area. This was done to avoid substantial time investment, searching for signs of Merlin activity, over extensive areas which may not facilitate the detection of breeding Merlin or identify areas of breeding activity (Fernandez-Bellon *et al.,* 2010). The search area therefore contained habitat which is suitable for foraging (within 300 m of potentially suitable breeding habitat) and all potentially suitable breeding habitat for Merlin within each survey square, as defined below. In cases where there was uncertainty as to the suitability of habitat for Merlin, surveyors were asked to liaise with the regional co-ordinator and to provide images of the areas, to allow further assessment. If the suitability of specific areas remained in question, then these areas were considered to be potentially suitable and included in the search area, in order to reduce the risk of overlooking Merlin which may nest in areas where the suitability was in doubt, and particularly given that many surveyors were surveying Merlin for the first time.

Unsuitable habitat: All areas of open water, urban and built up areas, semi-improved, improved and enclosed pastures and other enclosed agricultural land-uses and areas above 700 m in altitude (Hardey *et al*., 2009; Lusby *et al*., 2017) were considered to be unsuitable breeding habitat for Merlin.

Suitable foraging habitat: Unenclosed upland areas which include grass and heather moorland, natural grassland and bog which do not include suitable nesting opportunities for Merlin (as defined below) were considered as suitable foraging habitat.

Potentially suitable breeding habitat: All habitats which could be used for nesting by Merlin, as informed by knowledge of their nest site selection and requirements in Ireland (Lusby *et al*., 2017), were considered to be potentially suitable breeding habitat. This included all trees which could hold a suitable stick nest, which were located in or adjacent to suitable foraging habitats (as defined above), which included conifer plantation, open woodland, shelter belts, copses, tree lines, wooded islands on inland lakes, and isolated trees in open upland areas. The majority of Merlin nests in commercial plantation forest are located within 10 m of the forest edge (Lusby *et al*., 2017). Though nests may be located up to 60 m from the edge of the plantation, or within the forest interior close to the edge of fire-breaks or clearings (Norriss *et al.*, 2010), these criteria were used to define the forest areas suitable for breeding Merlin. Where it was possible to assess individual trees and to ascertain with confidence that there are no suitable stick nests present, then these trees were ruled out as unsuitable and did not require further survey effort. Merlin may also nest on the ground in heath or bog, where heather is 30–70 cm high (Hardey *et al*., 2009; McElheron, 2005), typically on sloping ground, and any areas which provided such opportunities were considered to be potentially suitable breeding habitat. Breeding Merlin have also been recorded using rocky crags and rock faces (David Norriss, personal communication), and boulders with suitable cover (McElheron, 2005) in a small number of cases, and such features were also considered to be suitable.

3.2 Survey techniques

Three survey techniques were employed to confirm occupancy and locate breeding Merlin, which were vantage point watches, sign searching and nest searches. These techniques were employed as appropriate to determine the highest level of breeding evidence of Merlin, based on the site-specific conditions. Vantage point watches were the primary method used in all survey squares and were supplemented with sign searching where this was deemed useful, based on the habitat conditions. In the Connemara Bog Complex SPA, the primary technique used to locate Merlin was nest searching, which is particularly suited to the landscape conditions and nest site choice of Merlin in this area. It was employed by surveyors working under the appropriate NPWS licence requirements (Sections 9 & 22 (9)(d) and Section 32, under the Wildlife Acts 1976–2018). Vantage point watches and sign searching were also carried out in the Connemara Bog Complex SPA. In addition to these survey techniques, available evidence of breeding Merlin in these SPAs was collated, to supplement the data generated through the survey. This was done to establish occupancy, and the highest level of breeding evidence of the species in the survey area.

3.2.1 Vantage point watches

Vantage point watches were carried out over all areas of potentially suitable breeding habitat within the defined survey area, to record Merlin activity and determine occupancy and breeding status. The location and number of vantage points were selected to ensure that all areas of potentially suitable breeding habitat within each survey square could be effectively watched. Vantage points were located at a maximum distance of 1.5 km from the area being watched, in order to allow reasonable confidence in detecting all Merlin activity associated with that area. Vantage point watches lasted a minimum of three hours and were undertaken in the morning (starting before 10.00 hours), or the evening (after 16.00 hours) where possible, and in suitable weather conditions. These were defined as visibility greater than 1 km, no precipitation and wind speed of less than Force 5 (fresh to strong breeze).

Figure 2 View from a vantage point location overlooking suitable breeding habitat in Derryveagh and Glendowan SPA. Photograph © Martin Moloney.

If Merlin nesting activity was recorded, then this area became the focus of future vantage point watches, to determine breeding status, area of breeding activity and outcome. The spacing of

Merlin nesting pairs in Ireland is typically greater than 2.7 km, however successful pairs have been recorded within 70 m of each other (Norriss *et al.,* 2010). Therefore recorded breeding activity in one part of a survey square did not preclude the continuation of vantage point watches in other parts of that 5 km x 5 km square or in adjacent survey squares. During vantage point watches, particular attention was given to other bird species including corvids, raptors, herons and gulls when passing over or interacting with potentially suitable breeding habitat for Merlin, as these species can elicit a response from breeding Merlin in proximity to nesting sites (Lusby *et al*., 2011). Merlin nests were not approached, and if birds were accidentally disturbed or flushed, the location details were recorded and the area was vacated immediately.

All details of the vantage point watches were documented using the recording form (Appendix 3), including a 10-figure grid reference (Irish National Grid) of the vantage point location (using a hand-held GPS unit), the start and finish times and details of all encounters with Merlin and other key species according to the specific behaviour and habitat codes listed below in Tables 2 and 3. All Merlin encounters were mapped on the relevant OSI survey map, according to the encounter number, and the full extent of flight lines viewed and direction of movement. The approximate or known location of Merlin nest sites were marked on the OSI survey map accordingly. The locations and number of each vantage point were marked on the OSI survey map, alongside the view from each vantage point. The location of sign searching transects were also marked, where sign searching was carried out. The survey square details and name, the SPA name, date, visit number, and start and finish times of the survey were also detailed on each OSI survey map in the appropriate space (as shown in Appendix 1).

Table 2 Behaviour codes and descriptions of behaviour used to record Merlin activity

Behaviour (Code)	**Description of behaviour**
Display (D)	Display flights, pair or single bird circling high over the potential nest site, may also be observed shivering their wings in flight
Flying (F)	Flying or commuting where no other behaviours are recorded
Hunting (H)	Actively hunting, typically low fast flights in pursuit of prey in suitable habitat
Perched (P)	Perched with no other behaviour recorded
on Ground (G)	Perched on the ground
Plucking (PL)	Plucking prey at perch
With prey (WP)	Carrying prey
Prey delivery (PD)	Adult delivering prey to a nest, or male delivering prey to female
Alarm (A)	Alarm calling or appearing agitated, usually close to a nest
Mobbing (M)	Mobbing other species, defensive behaviour usually close to a nest
Attending nest (AN)	Adult attending a nest, *e.g.* female incubating or brooding
Other (O)	Describe behaviour(s) not indicated by the categories above

Table 3 Habitat codes and description of habitats used to record Merlin activity

Habitat (Code)	Description of habitat
Heather moorland/bog (H)	Unenclosed heather-dominated moorland characterised by species such as heather, bilberry and purple-moor grass and/or blanket bog characterised by Ling heather *Calluna* sp. and Bell heather *Erica cinerea*, bog cotton (various spp.), deer grass (*Nardus stricta*) and mosses (various spp.). Typically grazed by deer and low densities of sheep.
Grass moorland (G)	Unenclosed grass-dominated moorland usually grazed by sheep. Characterised by species such as wavy hair grass, mat grass and heath rush. Stands of rushes *Juncus* spp. and bracken *i.e. Pteridium aquilinum* occasionally occur.
Rough grassland (RG)	Unenclosed or enclosed, neglected pastures occasionally stocked with sheep or cattle that have not recently been improved, re-seeded or fertilised. Usually contains long grass, waterlogged areas and stands of rushes.
Improved grassland (IG)	Enclosed pastures that have been drained, fertilised or re-seeded characterised by lush green grass vegetation and containing higher densities of livestock.
Mature forest (M)	Closed-canopy commercial conifer plantations including both first & second rotation crops. Usually >10 years old. Characterised by absence of shrub layer, except in rides between stands of trees and in small patches of unplanted ground or failed crop.
Young forest (Y)	First or second rotation commercial conifer plantations before the canopy closes. Characterised by prolific herb layer with varying shrub layer development, and brash for second rotation. Trees generally >1 m tall with large open spaces between lines of plantings.
Scrub (S)	Areas outside or away from plantation forests including bushy vegetation which is tended by humans. Scrub usually composed of one or more of the following species: Willow (Salix spp.), Gorse (*Ulex* spp.), Bramble (*Rubus* spp.), Alder (*Alnus* spp.), Birch (*Betula* spp.) and Bracken.
Other trees or woodland (T)	Other trees or woodland other than coniferous plantation which include native forest, open woodland, shelter belts, copses, tree lines, wooded islands on inland lakes and isolated trees.

3.2.2 Sign searching

Merlin select prominent features in suitable foraging habitat within breeding territories to pluck their prey. These plucking perches are typically in open habitat with good views of the surrounding landscape and include boulders, hummocks, fence posts, turf stacks, tree stumps and trees (Lusby *et al*., 2011; McElheron, 2005; Norriss *et al*., 2010). Checking potential plucking perches can reveal evidence of Merlin occupancy, in the form of signs, which include the remains of prey taken by Merlin, such as plucked feathers and body parts of avian prey, moth wings and Merlin pellets, white-wash, and moulted feathers (Fernandez-Bellon & Lusby, 2011; Hardey *et al*., 2009; Lusby *et al.*, 2011). As the breeding season progresses, signs may accumulate in proximity to the area of breeding activity (Norriss *et al*., 2010), and this can help to narrow down the search area, inform the best positioning of vantage point watches and indicate the potential location of nest sites.

The effectiveness of sign searching can vary depending on habitat conditions and the availability of suitable plucking perches within a search area (Lusby *et al*., 2011; Norriss *et al*., 2010). For example, extensive sign searching previously conducted in suitable foraging habitat did not reveal signs to indicate occupancy of Merlin, despite the fact that there was an active nest site in close proximity (Fernandez-Bellon *et al.*, 2010). In such situations, it is likely that Merlin use trees for plucking prey, including those at the edge or within forest plantation (Norriss *et al*., 2010). Other species also use plucking perches and discerning signs of Merlin from those of other raptors can be difficult in certain situations. For example, Kestrel (*Falco tinnunculus*) can be observed catching and subsequently feeding on invertebrate prey on hummocks in open bog (Dermot Breen personal communication), the remains of which could

be mistaken for Merlin. Sign searching is typically more profitable as the season progresses when breeding birds have been longer established in an area and signs may be more abundant. This technique was secondary to vantage point watches. Sign searching was employed, based on the probable success of the technique, on a site-by-site basis, taking into consideration the local habitat, the landscape characteristics, and the stage of the season. Therefore, in situations where sign searching was not deemed the optimal survey technique to determine Merlin occupancy, the emphasis was placed solely on vantage point watches over suitable breeding habitat.

Where sign searching was employed, transects of defined spacing in suitable foraging habitat within 300 m of potential breeding habitat were walked, and prominent features which may provide suitable plucking perches for Merlin were inspected. The spacing of transects varied from 20 – 150 m depending on the availability of suitable plucking perches. Transect routes were marked (lines with arrows) on the OSI survey map (Appendix 1). The start and finish times of sign searching were noted on the recording form. Where signs suspected to be indicative of Merlin were found, the relevant details were noted on the recording form to include the sign number, perch grid reference (10-figure grid reference using a hand held GPS), perch type (*e.g.* boulder, hummock, fence post etc.), whether the perch was re-used (Y/N), sign type (plucking, moth wings etc.), and number of prey species (based on identification of different prey species or by collating various body parts to assign a minimum number for each prey species). All signs were collected, placed in an individual sealable bag (single bag per plucking perch), and labelled with the date, site name, surveyor name, perch type and grid reference. Collecting signs can aid in confirming identification of the species of origin should this be necessary. All encounters with Merlin while conducting sign searching were noted and mapped accordingly on the OSI survey map.

Figure 3 The remains of passerine and moth prey, plucked by Merlin on a boulder, with the nest in a tree in the background. Photograph © John Lusby.

3.2.3 Nest searches

Nest searching was confined to the Connemara Bog Complex SPA, where the landscape conditions and the nest site selection of Merlin make this technique particularly suited. In the Connemara Bog Complex SPA, Merlin predominantly nest in trees or occasionally on the ground on densely vegetated islands on the inland lakes (Haworth, 1985; Haworth, 1986; Lusby *et al*., 2017; Dermot Breen personal communication). The trees used by Merlin on these islands are typically low and it was possible to assess the presence of stick nests in all trees. The suitability of all lakes in the Connemara Bog Complex SPA were assessed using aerial maps and previous survey data, to identify all lakes with islands which provide potentially suitable breeding habitat for Merlin. All islands considered to be potentially suitable were accessed by experienced surveyors, under valid NPWS licences, to visit Merlin nests. All stick nests located were inspected to determine use by Merlin. Sign searching was also carried out in the vicinity of islands, where there were suitable and accessible perches, which could be used by Merlin for plucking prey. All observations of Merlin while searching for nests were recorded, as approaching nests can elicit a response from resident breeding Merlin, which provides evidence to indicate breeding.

3.2.4 Merlin records

Records of Merlin in the breeding Merlin SPA network during the survey period (April to mid-July) were collated from available sources to supplement the data generated on Merlin activity, using the survey techniques described above. A request for information on breeding Merlin was made via BirdWatch Ireland and IRSG social media platforms and individual bird surveyors and representatives of bird monitoring and conservation projects operating in the survey area were contacted via email. Information on breeding Merlin was received via a specialised online reporting platform, or by email directly to the survey co-ordinator. All information on breeding Merlin received from within the breeding Merlin SPAs during the survey period was validated and used accordingly, alongside data generated through the survey, to assess the distribution and status of Merlin in the survey area.

3.3 Survey schedule

The Merlin Survey was carried out over 15 weeks from 1 April to 15 July 2018. Four visits to survey squares were scheduled over this survey period. The first three visits were required. If there was no evidence of Merlin recorded during the first three visits, then the fourth visit was optional, but recommended. Each visit was spaced by at least one week. The duration of each survey visit could vary from a single day to several days, depending on the size of the defined search area, the quantity of potentially suitable breeding habitat and the number of vantage point watches required to cover all potentially suitable breeding habitat.

The **first visit** (1 April – 7 May) required becoming familiar with the survey square and the search area within, and informed the best approach to undertaking the survey, including the resource requirements to effectively survey the area for breeding Merlin. Any further unsuitable habitat recorded on this visit was excluded from the search area and marked on the OSI survey map accordingly. The locations of vantage point watches to overlook all areas of potentially suitable breeding habitat were selected and vantage point watches were conducted. This visit aimed to establish occupancy of Merlin and identify potential nesting areas.

The **second visit** (1 May – 7 June) aimed to establish occupancy of Merlin within the defined search area and to identify areas of potential breeding activity based on evidence of Merlin encounters and associated behaviour and/or signs. Vantage point watches were carried out as informed by the first visit, and sign searching was conducted, if deemed appropriate.

The **third visit** (1 June – 7 July) aimed to establish evidence of breeding, with emphasis on locating active nests, or areas of breeding activity, where these were not already located. Where areas of nesting activity were known or suspected, the emphasis was placed on

vantage point watches. Where this information was not available, sign searching was also carried out, informed by earlier visits and which included the revisiting of plucking perches, where signs were previously recorded.

The **fourth visit** (1 July – 15 July) aimed to confirm breeding status within the search area, and to identify nest locations and establish breeding outcomes where relevant. The fourth visit relied primarily on vantage point watches, which were supplemented by sign searching, if required and deemed appropriate.

In the Connemara Bog Complex SPA, all areas of potentially suitable breeding habitat on the densely vegetated islands on inland lakes were visited on at least one occasion from 18 April to 15 July 2018. If the area was searched thoroughly (*e.g*. all trees checked for stick nests) and there was no indication of the presence of breeding Merlin, then these areas did not require further visits. If evidence of Merlin was recorded, then these areas were visited subsequently to locate the nest and determine the outcome of breeding (if this was not possible on the initial visit).

3.4 Data recording

All survey data was captured on the recording form (Appendix 3) and OSI survey map (Appendix 2) and submitted to the regional co-ordinators or sent by post to the survey co-ordinator. Surveyors were asked to make copies of data prior to sending by post to ensure that data was not lost. Alternatively, survey data was entered directly into the survey excel spreadsheet and emailed to the survey co-ordinator, in which case the OSI survey maps were scanned and sent by email or sent in the post separately. Surveyors were not required to return aerial images of the survey square unless these were used for recording specific survey data. All survey data was collated into a single excel spreadsheet for analysis and interpretation. Relevant data (*e.g*. the location of vantage points, Merlin observations, confirmed breeding locations etc.) were mapped in QGIS 2.18 to allow visual exploration and to assess Merlin occupancy, breeding densities and population estimates in the survey area as outlined below.

3.5 Merlin occupancy and breeding densities

Each 5 km x 5 km survey square was categorised according to the highest level of breeding evidence of Merlin recorded within, based on the criteria below. The criteria used to define occupancy and breeding status was informed by previous Merlin surveys in Ireland and Britain, to ensure comparability (Ewing *et al*., 2011; Lusby *et al*., 2011) and adapted for the specific purposes of this survey, as shown below in Table 4.

Table 4 Classification criteria for Merlin survey records

Status	Description of Merlin activity, behaviour and observations
Unoccupied	No evidence of Merlin (fresh signs, sightings or calls) recorded
Occupied territory	At least one Merlin seen or heard, or fresh signs of occupation (plucking, pellets, droppings or moulted feathers) confirmed to be Merlin found on at least two occasions separated by at least one week
Breeding pair	Male and female observed simultaneously, or both adults observed individually on at least three occasions in the same area (within 1 km) in suitable breeding habitat, courtship display (including the male bringing food to the female), copulation, or a single bird showing behaviour indicative of breeding, including entering or leaving a nest, delivering prey to a nest, repeatedly alarm-calling or mobbing, or evidence of a nest, including eggs or eggshells, young in the nest or recently fledged young seen or heard.

Breeding densities were calculated based on the total numbers of confirmed breeding pairs and the numbers of occupied territories recorded within the defined survey area. For this purpose, occupied territories were considered to represent 'possible pairs', as these were areas where Merlin were recorded in, or close to, suitable breeding habitat, which were located away from known breeding pairs and where a confirmed breeding pair were not recorded. To avoid overestimation of the numbers of individual occupied territories within the survey area, observations of Merlin which were within 3 km of a confirmed breeding pair or occupied territory (based on observations) were considered to be associated with that breeding pair or occupied territory and were counted accordingly. Therefore, only observations of Merlin which were more than 3 km from other observations, including the location of known breeding pair, were considered as a distinct occupied territory. This distance was informed by the spacing of nesting pairs in Ireland, which are typically greater than 2.7 km (Norriss *et al*., 2010). Although information on the home range size and movements of breeding Merlin in Ireland is not known, and are likely to vary depending on a range of factors including habitat extent and condition, land use and prey availability.

To determine the spacing between nesting pairs, the distance to the closest nest site was determined for each known nest location in the Connemara Bog Complex SPA in QGIS 2.18. The mean distance between nests was calculated based on all known pairs. This estimate of spacing between nesting pairs was only performed for Merlin in the Connemara Bog Complex SPA, as this is the only SPA which received complete survey coverage.

3.6 Population estimates

Merlin population estimates were derived for the six SPAs by calculating the number of confirmed breeding pairs and the number of possible pairs (based on occupied territories) recorded within the survey area. These figures were extrapolated to the extent of the breeding Merlin SPAs to provide a population size of confirmed and possible pairs in the six breeding Merlin SPAs.

3.7 Breeding performance and habitat selection

To assess Merlin breeding performance, all breeding pairs which were confirmed within or close to the SPA were monitored to determine the outcome of the breeding attempt. This included all breeding pairs within the survey area, and all pairs which were confirmed elsewhere in or close to the SPA, via records and follow up survey effort. Three measures were used to quantity the breeding performance of confirmed breeding pairs, as defined below.

Table 5 Classification criteria to record Merlin breeding attempts

Breeding outcome	Description of breeding outcome
Breeding outcome unknown	The outcome of breeding was not determined (*i.e.* it was not possible to confirm whether the pair successfully fledged one or more young)
Failed breeding attempt	Breeding attempt which did not result in young fledging
Successful breeding attempt	Breeding attempt resulted in one or more young fledging

For successful breeding attempts, the number of fledged young were recorded where possible, by counting young in or close to the nest via vantage point watches. In the Connemara Bog Complex, attempts were made to locate and visit the nest of all confirmed breeding pairs, to collect data on brood size, and young were ringed on these nest visits. For failed breeding attempts, the cause and timing of failure was determined where possible.

To investigate nest site selection, the nest site type was recorded for each confirmed breeding pair where the nest was located or the nest habitat was determined and were classed as either tree-nesting or ground-nesting. Tree nests were further defined using categories as per Lusby *et al.* (2017) to describe Merlin nest site selection in Ireland, which included, coniferous forest, densely vegetated islands on water bodies, open woodland, isolated trees, shelter belts and copses.

4 Results

4.1 Survey coverage

A total of 60 surveyors participated in the survey, which included 31 NPWS staff, 21 volunteer surveyors, four surveyor contractors and four regional co-ordinators. The number of surveyors working in each SPA ranged from three (Lough Nillan Bog SPA) to 21 (Slieve Aughty Mountains SPA).

The total area surveyed was 667.09 km^2, which included 19 survey squares (475 km^2) in addition to the Connemara Bog Complex SPA (192.09 km^2). In the survey area, 494.93 km^2 (74%) was within the breeding Merlin SPA network, and the remaining 172.15 km^2 (26%) was lands bordering the SPAs. The proportion of each SPA surveyed ranged from 14.5% (Wicklow Mountains SPA) to 100% (Connemara Bog Complex SPA). The portion of the breeding Merlin SPA network surveyed (494.93 km^2), represents 29% of the six breeding Merlin SPAs. The total survey time was 1,953.84 hours, which included 1,617.71 hours surveying the 19, 5 km x 5 km survey squares, and an estimated 336.13 hours to survey the Connemara Bog Complex SPA. The number of surveyors per 5 km x 5 km survey square ranged from one to nine, with an average of three surveyors per square. Five surveyors covered the Connemara Bog Complex SPA, with the majority of this area covered by a single surveyor.

Of the total survey time (1,617.7 hours) to cover the 19 survey squares, most *i.e.* 1,480.6 hours was spent on vantage point watches and 94.3 hours spent sign searching, with the remaining time (42.77 hours) spent in transit, assessing habitat suitability and identifying the location of vantage point watches. In the Connemara Bog Complex SPA, an estimated 220 hours was spent searching for nests, and 94.7 hours carrying out vantage point watches. The average time required to survey each survey square was 85.1 hours and ranged from 8.7 to 214.3 hours per square. The Slieve Aughty Mountains SPA required the most time investment per survey square (n = 5) with an average of 140.2 hours spent per survey square, whereas the least time required per survey square was in the Wicklow Mountains SPA which required and average of 61.9 hours per square (n = 4).

As detailed in Table 6, the overall survey time in each SPA expressed per 100 km2 of survey area, was highest in the Slieve Aughty Mountains SPA, which required over three times the time investment as the Connemara Bog Complex SPA, and over twice the time investment as the Owenduff/Nephin SPA and the Wicklow Mountains SPA.

Table 6 The time spent surveying in each SPA

SPA	Area (km^2)	Area surveyed (km^2)	Survey time (hrs)	Survey time (hrs)/100 k m^2
Derryveagh and Glendowan Mountains. SPA	314.96	125	356.06	284.84
Lough Nillan Bog SPA	41.16	25	81.31	325.24
Owenduff/Nephin Complex SPA	257.07	100	231.38	231.38
Slieve Aughty Mountains. SPA	594.82	125	701.15	560.92
Wicklow Mountains. SPA	302.07	100	247.81	247.81
Connemara Bog Complex SPA	192.09	192.09	336.13	174.98
Total	1702.17	667.09	1,912.41	

Of the 19 survey squares in the five SPAs, 11 (58%) received four visits, seven (37%) received three visits and one (5%) received two visits. Eighteen survey squares (95%) received first and second visits, all survey squares received third visits, and 12 (63%) survey squares received fourth visits. In the Connemara Bog Complex SPA, all areas of suitable breeding habitat were visited at least once during the survey period.

In addition to the survey area as defined above, an additional seven squares (5 km x 5 km) received survey coverage in the Slieve Aughty Mountains SPA (n = 4) and Derryveagh and Glendowan Mountains SPA (n = 3), which focused on following up on records of Merlin received, to confirm breeding status and breeding performance. A total of 113.72 hours were spent surveying these additional areas, which included 106.49 hours vantage point watches and 7.23 hours searching for signs. All survey work in these areas was conducted by three survey contractors.

4.2 Survey techniques

4.2.1 Vantage point watches

A total of 141 vantage point locations were used to survey all areas of potentially suitable breeding habitat in the survey squares (S.E.[2] = 1.19, n = 19, range = 2 – 18). The number of vantage point locations used per survey square was highest in the Slieve Aughty Mountains SPA, with an average of 12.6 vantage point locations per square (n = 5) and lowest in Owenduff/Nephin SPA, with four vantage points per survey square (n = 4). The number of hours spent on vantage point watches in survey squares was 1,435.22 hours (S.E.= 11.90, n = 19, range = 8.4 – 208.16). In the Connemara Bog Complex SPA, a total of 16 vantage point locations were used, and watches were conducted over 94.68 hours.

Merlin observations (n = 22) were recorded on 17 individual vantage point watches. This total, across all vantage point watches (1,575.3 hours), equates to one sighting per 71.6 hours of watches. Vantage point watches recorded the highest level of breeding evidence for Merlin in eight (42%) of the 19 survey squares, and for one occupied territory in the Connemara Bog Complex SPA. Of the 22 Merlin observations, most were recorded in the Wicklow Mountains SPA (n = 11), followed by Connemara Bog Complex SPA (n = 5), Slieve Aughty Mountains SPA (n = 3), Owenduff/Nephin SPA (n = 2), with a single observation recorded in Derryveagh and Glendowan SPA and no sightings recorded on vantage point watches in Lough Nillan Bog SPA. Merlin were most frequently observed in the Connemara Bog Complex SPA and the Wicklow Mountains SPA per time spent on vantage point watches, with one sighting every 19 hours of watches in both SPAs.

The average distance that Merlin were observed from the vantage point location was 363 m (S.E. = 51, n = 22, range = 20 – 1,012 m). Merlin were most often observed in flight (n = 7), in flight and perching (n = 6) and hunting (n = 6), with single observations of a bird carrying prey, mobbing a Kestrel and attending a nest. The majority of Merlin observations during vantage point watches were recorded in May (n = 10), followed by April (n = 6), June (n = 3) and July (n = 3). Merlin were most frequently observed on vantage point watches in April and May based on survey effort, with one sighting per 45.5 hours and 49.8 hours respectively in each month. Merlin were observed at a frequency of one observation per 87.6 hours spent on vantage point watches in July, and were least frequently recorded in June based on survey effort in that month, with one observation recorded per 120.9 hours of vantage point watches.

[2] S.E. Standard error

4.2.2 Sign searching

Sign searching was conducted over 94.3 hours in 15 (79%) survey squares. Signs which were suspected to be of Merlin were recorded in eight (53%) of the 15 survey squares. A total of 17 signs were recorded in these 15 survey squares, with an average of 2.5 signs per survey square (range = 1 – 6). Signs were recorded most frequently on hummocks (n = 10) and boulders (n = 7), with a single sign on a turf pile and two signs on 'other' perches. Passerine feathers (n = 16) were the most frequently recorded sign, followed by pellets (n = 3) and moth wings (n = 2). Two different types of signs (feathers and pellets) were recorded on three perches.

In the eight survey squares in which signs suspected to be of Merlin were recorded, the presence of Merlin was confirmed in six survey squares by observations on vantage point watches (n = 4), observations on vantage point watches and ad hoc records combined (n = 1), and ad hoc records (n = 1). There was a single sign recorded in two survey squares, where there were no observations of Merlin recorded, however this information was not enough to classify these squares as 'occupied'.

There were no signs located in the remaining seven survey squares where sign searching was carried out. There were no observations of Merlin in five of these survey squares. A breeding pair which failed early in the season was recorded in one square, and one square was deemed to be occupied. Merlin were not observed during sign searching.

4.2.3 Nest searches

The Connemara Bog Complex SPA was surveyed between the 18 April and 15 July 2018, over 23 survey dates, amounting to an estimated 220 hours. A total of 280 wooded islands on 98 lakes were assessed for their suitability and for the presence of breeding Merlin. Breeding Merlin were recorded on five islands, and the nests were located in all cases.

Figure 4 Densely vegetated islands on an inland lake in the Connemara Bog Complex SPA, which provide suitable nesting sites for Merlin. Photograph © John Lusby.

4.2.4 Merlin records

Ten records of Merlin within or bordering the breeding Merlin SPA network within the survey period (April to mid-July) were received. Six records of Merlin were received from the Slieve Aughty Mountains SPA, and two records from each of Lough Nillan Bog SPA and Derryveagh and Glendowan SPA. Of these records, three were within the survey area and seven were outside the survey area. Eight sightings were of single birds, in flight (n = 6), hunting (n = 1) and with prey (n = 1), two sightings were of a pair, one of which was a pair displaying and copulating, and the other was a pair mobbing a Raven (*Corvus corax*).

4.3 Merlin occupancy and breeding densities

Of the 19 survey squares in five SPAs, breeding pairs were confirmed in four squares (21%), six squares were confirmed to be occupied (32%), and nine squares were classed as unoccupied (47%). In addition, six breeding pairs were confirmed in the Connemara Bog Complex SPA, within five 5 m x 5 km squares, and a single territory was recorded in one square.

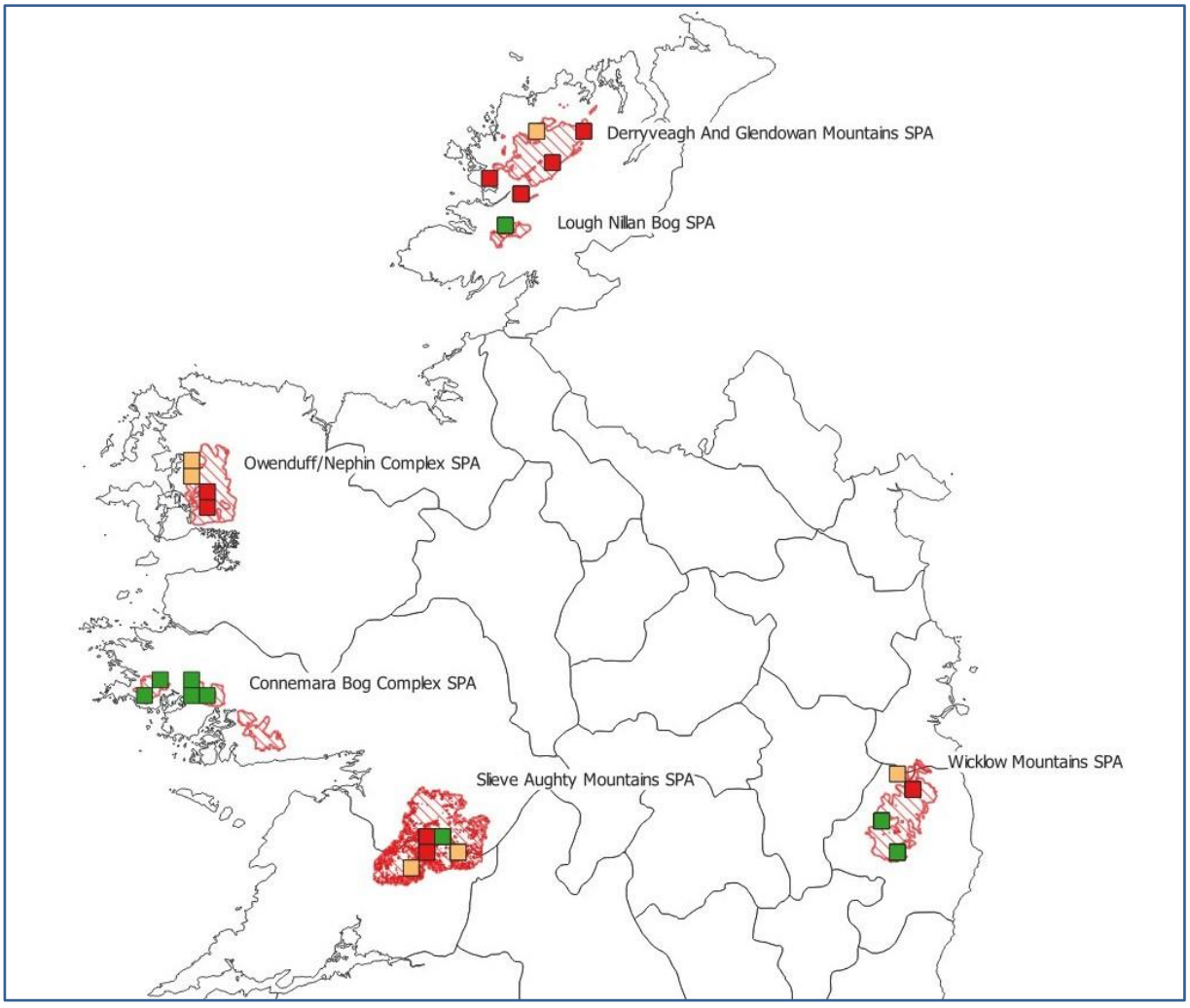


Figure 5 The status of Merlin in all 5 km x 5 km survey squares (n = 19) and the Connemara Bog Complex SPA, showing squares which held breeding pairs (green), occupied territories (orange) and those which were unoccupied (red).

A total of ten breeding pairs were confirmed and eight occupied areas in the survey area (667.09 km^2). Merlin breeding densities were estimated at 1.5 – 2.7 pairs per 100 km^2 in the survey area based on the number of confirmed and possible pairs. Within the portion of the

breeding Merlin SPAs surveyed (494.93 km^2), Merlin breeding densities were estimated at 1.6 – 2.4 pairs per 100 km^2, based on eight confirmed pairs and four occupied areas recorded in the breeding Merlin SPA network. The mean distance between pairs in the Connemara Bog Complex SPA was 3.2 km (S.E. = 340 m, n = 5, range = 2.8 - 4.6 km).

Of the ten breeding pairs confirmed within the survey area, five were confirmed via nest searches, all of which were in the Connemara Bog Complex SPA. Three were confirmed via vantage point watches in the Wicklow Mountains SPA (n = 2) and in the Connemara Bog Complex SPA (n = 1). One pair in the Slieve Aughty Mountains SPA was confirmed via vantage point watches (in addition to ad hoc records of Merlin received from other observers), and one pair in Lough Nillan Bog SPA was confirmed solely via ad hoc records received from other observers. Of the occupied territories recorded, seven (87.5%) were confirmed via vantage point watches. One occupied territory in the Slieve Aughty Mountains SPA was confirmed via independent records. Of the ten breeding pairs, eight (80%) were within the breeding Merlin SPAs and two (20%) were located outside the SPAs. Of the eight occupied areas, four (50%) were within the SPAs and four (50%) were outside the SPAs.

Table 7 Status of survey squares

Survey square/area	SPA	Status	No. breeding pairs	No. occupied territories
IB70_NE	Derryveagh and Glendowan Mountains SPA	Unoccupied	-	-
IB80_SE	Derryveagh and Glendowan Mountains SPA	Unoccupied	-	-
IB91_SE	Derryveagh and Glendowan Mountains SPA	Unoccupied	-	-
IB92_SW	Derryveagh and Glendowan Mountains SPA	Occupied	-	1
IC02_SE	Derryveagh and Glendowan Mountains SPA	Unoccupied	-	-
IG89_SW	Lough Nillan Bog SPA	Breeding pair	1	-
IF80_NE	Owenduff/Nephin Complex SPA	Unoccupied	-	-
IF80_SE	Owenduff/Nephin Complex SPA	Unoccupied	-	-
IF81_NW	Owenduff/Nephin Complex SPA	Occupied	-	1
IF81_SW	Owenduff/Nephin Complex SPA	Occupied	-	
IR69_NW	Slieve Aughty Mountains SPA	Breeding pair	1	-
IR58_NW	Slieve Aughty Mountains SPA	Occupied	-	1
IR59_NE	Slieve Aughty Mountains SPA	Unoccupied	-	-
IR59_SE	Slieve Aughty Mountains SPA	Unoccupied	-	-
IR69_SE	Slieve Aughty Mountains SPA	Occupied	-	1
IO00_SW	Wicklow Mountains SPA	Breeding pair	1	1
IO01_NE	Wicklow Mountains SPA	Occupied	-	2
IO11_SW	Wicklow Mountains SPA	Unoccupied	-	-
IT09_SE	Wicklow Mountains SPA	Breeding pair	1	-
Polygon 1	Connemara Bog Complex SPA	Breeding pair	3	-
Polygon 2	Connemara Bog Complex SPA	Breeding pair	3	-
Polygon 3	Connemara Bog Complex SPA	Occupied	-	1
Total			10	8

4.4 Population estimates

A total of eight breeding pairs and four occupied territories were confirmed within the portion of the breeding Merlin SPAs surveyed (494.93 km^2). The number of breeding pairs and occupied territories recorded within the portion of the SPAs surveyed, extrapolated to the entire area of the six SPAs (1702.17 km^2), provides a population estimate of 27.5 to 41 pairs. The best estimate of the breeding Merlin population across the six SPAs is 34 breeding pairs, which is the mid-range of the extrapolated minimum (27.5 breeding pairs) and the extrapolated maximum (41 breeding pairs) population. As stated, this population estimate is derived from a sampled area of the breeding Merlin SPAs. Efforts were taken to reduce bias and ensure that the area surveyed is representative of the wider breeding Merlin SPAs, however given the lack of data on Merlin home range size and habitat requirements in the Irish context there are inherent biases which may influence these population estimates. Such factors include variation in habitat conditions and suitability for breeding Merlin and their distribution and breeding densities across the SPAs.

4.5 Breeding performance and habitat selection

In addition to the ten breeding pairs recorded within the survey area, four pairs were confirmed via records received, and additional survey effort. Of 14 breeding pairs confirmed within and bordering the breeding Merlin SPAs, it was possible to determine the outcome of breeding for eight pairs, of which seven were successful and one failed. Merlin had a breeding success of 87.5% (n = 8), with an average of 3.5 young fledged per successful pair (S.E. = 0.48, n = 7, range = 2 – 5), and a productivity of 3.1 young per breeding attempt (S.E. = 0.61, n = 8, range = 0 – 5). A total of 17 young were ringed from five nests, all in the Connemara Bog Complex SPA.

Figure 6 A brood of four Merlin which were ringed at a nest in the Connemara Bog Complex SPA. Photograph © John Lusby.

All nests which were located (n = 8) were in trees, five (62.5%) in trees on densely vegetated islands on inland lakes in the Connemara Bog Complex SPA, two (25%) in small copses and one (12.5%) in conifer plantation.

5. Discussion

5.1 Survey design

This was the most extensive survey of Merlin undertaken to date in Ireland and the first to census the population within the breeding Merlin SPA network. It demonstrated that a large-scale, and strategic survey of Merlin, can be implemented using an extensive network of experienced and trained surveyors. It provides an approach which can be followed and improved on, where required, for future surveys. The survey design was informed by previous, smaller-scale survey efforts for Merlin in Ireland (Lusby *et al*., 2011). Combined with the outputs of the current survey, it provides clear and practical recommendations to facilitate enhanced monitoring of the species into the future. As such, it is important to recognise the aspects of the survey design which were successful and equally to understand the limitations of the survey so that future surveys can be refined accordingly.

Site selection, in particular, the decision to include lands bordering the breeding Merlin SPA network within the randomised sampling approach, was validated by the findings of the survey. The findings highlight that areas bordering the breeding Merlin SPAs are important for breeding Merlin. There was a higher density of breeding pairs and occupied territories recorded in lands bordering the SPAs compared to within the SPAs. This distribution of Merlin breeding pairs in relation to the SPA boundaries has important implications for the conservation of the species, and the management of the breeding Merlin SPA network, which is discussed in detail below. In relation to the survey design, it was appropriate to assess Merlin populations based on randomised sampling and not restrict the survey effort to within defined boundaries of the SPAs, as this would not have accurately represented Merlin populations associated with or dependent upon those sites. The size of the survey area sampled can determine the efficacy or otherwise of the survey. The challenge was to select a survey area of sufficient size to adequately represent the breeding Merlin SPA network and allow for extrapolated estimates of population size for the breeding Merlin SPA network. A minimum threshold of 25% coverage of the breeding Merlin SPA network was set. This threshold was reached and marginally exceeded. However, it is clear that based on the demanding nature and the effort required to effectively survey this area that coverage could not have been extended further with the resources available. A comprehensive survey of the breeding Merlin SPA network would provide the most reliable population estimate and given that there is now an established survey design and increased capacity to deliver large-scale Merlin surveys, this should be the aim of future surveys of the species in the breeding Merlin SPA network. However, based on the experiences of the current survey, it was necessary to sample a representative portion of the breeding Merlin SPA network to assess Merlin populations within. It would be worthwhile to consider staging survey effort over more than one breeding season in future years (for example focusing on one or two SPAs in detail in a single year) if a complete survey was deemed desirable.

One of the main limitations in achieving greater survey coverage was the criteria set for surveyor's skills requirements, and specifically that surveyors were identified and invited to participate based on their known level of survey experience, as opposed to an open recruitment system. The latter would have undoubtedly resulted in a larger volunteer surveyor base and thus increased coverage. In this regard, there is a trade-off between increasing survey coverage and potentially compromising confidence in the survey findings. The challenges and demanding nature of surveying for Merlin, compared to other raptor species for which nationwide surveys have been implemented in Ireland (Madden *et al*., 2009; Ruddock *et al*., 2016), was highlighted by the low observation rates (one sighting per 71.6 hrs of vantage point watches). The low return rate of observations also emphasises the challenges with maintaining motivation among all surveyors over the survey season, given that the majority of surveyors did not observe the target species. The survey workshops and maintaining regular communication with surveyors are essential in this regard, both to build capacity and to manage expectations and motivation and survey workshops should be an essential component of any future survey on the species. As shown by the data on Merlin collected and the survey

coverage achieved, the survey contractors were an essential component of this survey, and are necessary for any future, large-scale surveys for the species that utilise similar methods.

The time investment required to effectively census Merlin within the survey area highlights the significant challenges with surveying the species. The time spent surveying for Merlin was over ten times greater than the time spent surveying for Hen Harrier (*Circus cyaneus*) as part of the Hen Harrier Survey 2015 (Ruddock *et al*., 2016), based on survey areas of equal size. Although the Merlin survey required substantial investment overall, the time requirements to achieve effective coverage varied in each SPA and this has important implications for the future monitoring of the species. The Slieve Aughty Mountains SPA presented the greatest challenges, and required a greater number of surveyors, including survey contractors, as well as more vantage point locations and more time to effectively cover the survey area in this SPA. In contrast, the Connemara Bog Complex SPA, which is the closest to the Slieve Aughty Mountains SPA required the least time, even though more breeding pairs were recorded in this SPA compared to all other SPAs combined. The stark contrast in the time investment required to survey these two SPAs is likely to be partly related to the experience of the surveyors working in the Connemara Bog Complex SPA, and the knowledge of Merlin and survey techniques accumulated through monitoring of the species in this area in recent years (Lusby *et al*., 2017). However, a more influential factor is undoubtedly related to the landscape conditions and the nest site choice of Merlin in the Connemara Bog Complex SPA. It is widely accepted that forest nesting Merlin are more difficult to locate compared to pairs nesting in other habitats, and therefore it stands to reason that in areas with extensive forest cover, the survey time requirements are increased. Over half of the surface area of the Slieve Aughty Mountains SPA is conifer plantation (Moran & Wilson-Parr, 2015), and this is reflected in the substantial time spent surveying in this area and the limited observations of Merlin recorded for this survey effort. In contrast, in the Connemara Bog Complex SPA, due to the open nature of this landscape and nesting ecology of Merlin in this area, it is possible to assess the presence of the species in all areas of suitable breeding habitat. The survey techniques used in the Connemara Bog Complex SPA to locate Merlin facilitate greater coverage, but also greater confidence in the resulting information on breeding Merlin. However, although there is limited planted forest in the Connemara Bog Complex SPA, there is substantial conifer plantation surrounding the SPA, which is suitable breeding habitat for Merlin (Haworth, 1985; Haworth, 1986; Lusby *et al*., 2017). There is limited knowledge of the species in the planted forests adjacent to the SPA and the same challenges would apply to surveying Merlin in these areas as in other forest dominated landscapes. The Connemara Bog Complex SPA is unique (at least within the context of the other SPAs), in terms of the comparative ease with which breeding Merlin can be surveyed and this variation on a regional basis should be taken into account when planning future monitoring efforts to generate data on breeding densities and trends for Merlin.

Although the time requirements were substantial in the surveyed areas, less strategic approaches taken in the “additional” survey areas involved less time but produced a higher return per survey effort. This highlights the inherent difficulties and somewhat variable and localised nuances associated with surveying Merlin in Ireland. Several monitoring studies on Merlin have been undertaken to date, which have generated data on breeding performance (Lusby *et al*., 2017; Norriss *et al*., 2010) and nest site selection (Haworth, 1985; Haworth, 1986; Lusby *et al*., 2017; McElheron, 2005; Norriss *et al*., 2010), and there is a good understanding of these aspects of the species’ ecology. Due to the discrete nature of Merlin, it seems that building up knowledge of the species, their habits and nesting ecology over consecutive years in specific areas, is conducive to monitoring the species. In comparison, the randomised sampling approach which requires cold-searching areas where there is limited knowledge of Merlin, as applied by the current survey, is more difficult and labour intensive. However, this approach is required to establish data on population size and distribution, which have been knowledge gaps up to this point (BirdWatch Ireland, 2011). We recommend that future monitoring of the species is targeted to address these knowledge gaps, and this can be done by defining the search area and the survey efforts, to allow estimates of breeding densities to be established. This would have significant benefits in furthering our understanding of Merlin across different regions and is outlined in the recommendations accordingly.

One of the limitations of a survey of Merlin in Ireland is the uncertainty over null records in certain situations, and the potential for under-recording, and therefore under-representing Merlin populations. This has been an issue for previous surveys on Merlin in Ireland (Lusby *et al*., 2011) and Britain (Rebecca & Bainbridge, 1998). Lusby *et al.* (2011) stressed that absence of breeding Merlin should not be determined from negative results of surveys in situations where detection of Merlin is difficult. The 2010 Pilot Merlin Survey assessed the efficiency of survey techniques for detecting breeding Merlin in Ireland (Lusby *et al*., 2011) and the lessons learned were applied to the design of the current survey, to maximise survey effort and resources, and to reduce the risk of overlooking Merlin. Several measures were taken to further reduce the risk of under-recording Merlin, which included: deploying survey contractors to the survey areas which were considered to be the most challenging (thereby providing for maximising of survey effort), limiting the size of the survey unit, training of surveyors, and also reviewing the criteria used to allocate breeding status of Merlin, which takes account of the difficulty in confirming breeding (e.g. occupied territories were deemed to represent 'possible pairs'). However, based on the techniques employed, it is not possible to entirely rule out the potential for under-recording breeding Merlin. The degree to which breeding Merlin may have been missed within the survey area is not known, and this should be recognised as a limitation when interpreting the results. The challenges of surveying Merlin, and thus potential to overlook the species varies according to a range of factors. However, the nesting habitat and extent of forest cover are probably the most influential factors in affecting the reliability of survey findings. It was not possible to incorporate an evaluation of the efficiency of survey techniques within the current survey, due to the small sample size of survey squares and low densities of Merlin within, in addition to the significant time investment required to perform a validation of survey effectiveness. For example, the 2010 Pilot Merlin Survey covered an area seven times smaller than the area for this survey, but required over three times the time investment on behalf of professional surveyors to cover the same area. This limitation will continue to be a challenge for Merlin surveys. However, as shown by this survey, the ability, time, and resource requirements to survey the species vary significantly in different areas. This should be taken into consideration in planning future monitoring and surveys. In addition, consideration should be given to other survey techniques, which could reduce the resource requirements and increase the reliability in detection of Merlin, and these are discussed below.

5.2 Survey techniques

Vantage point watches were the main survey technique used and provided information on Merlin occupancy in eight of the survey squares, as well as evidence of a single breeding pair in the Connemara Bog Complex SPA. In the absence of other techniques, and where nest searching is not possible, vantage point watches are the most reliable technique for detecting breeding Merlin. Nevertheless, this technique is labour intensive and as demonstrated by this survey, typically generates low observation rates. The low observation rates are likely related to the fact that Merlin occur in low densities and are widely dispersed but also relates to their discrete breeding behaviour.

The primary limitation with this technique is the lack of certainty over the reliability in detecting breeding Merlin in certain situations. Lusby *et al.* (2011) stressed that due to the discrete nature of the species, the absence of breeding Merlin cannot be determined from negative results of vantage point watches, and this is particularly the case in forest habitats. Merlin nesting in forests tend to select concealed nests (Sieg & Becker, 1990) which are seldom directly visible (Hardey *et al*., 2009), therefore observations around nest sites may be restricted. Based on the results from the vantage point watches conducted in a range of situations as part of the Pilot Merlin Survey, it was suggested that watches at nests in more 'open' habitats, such as open woodland, islands, small blocks of forest or shelter belts, yield more encounters than nesting sites in more 'concealed' habitats, such as large and dense forest plantations (Lusby *et al*., 2011). This survey showed that observation rates from vantage point watches were highest in the Connemara Bog Complex SPA, where all recorded pairs nested on small islands on lakes surrounded by open bog. It is possible that the higher observation rates may be due to higher breeding densities, however Merlin were also observed at greater distance in

Connemara than in the other SPAs which is influenced by the greater visibility afforded by this more open landscape. Although observations rates were high in the Connemara Bog Complex SPA in the context of the other SPAs, they were low overall when it is considered that the majority of vantage point watches were carried out in occupied or breeding territories and in view of nest sites. In addition to the fact that Merlin are more difficult to detect in forest-dominated landscapes, a greater number of vantage points are required to effectively cover forest areas. The distance at which Merlin were observed in this survey emphasises the need to use a large number of vantage point locations, which are positioned close to potentially suitable habitat. This increases the time and resource requirements of the survey. Aside from the Connemara Bog Complex SPA, the majority of vantage point watches in this survey overlooked forest plantation, and this explains the time investment, and the low encounter rates.

The timing and duration of vantage point watches is also an important consideration, which can affect observation rates and survey findings. Previous studies recommend vantage point watches of two hours (Rebecca & Bainbridge, 1998; Gilbert *et al*., 1998), or four to six hours duration (Hardey *et al*., 2009). Lusby *et al*. (2011) showed that during full day watches of active nests, there were long periods of time, on occasion exceeding three hours, in which Merlin were not observed, despite the fact that a known active nest was within view. Vantage point watches of three hours in length were conducted as part of this survey, however for future surveys, vantage point watches of longer duration should be considered on a site and habitat specific basis and targeted to the areas where visibility of Merlin is likely to be low. This survey also showed that, although observations rates were very low overall, Merlin were more frequently observed in April and May based on time invested in vantage point watches, with observations lowest in June and increasing again in July. This should be taken into account when planning surveys to maximise return for effort and ensure that surveys are timed to coincide with the stages of the breeding cycle that Merlin are most likely to be detected, while also ensuring that pairs which fail early in the season are recorded.

Hardey *et al*. (2009) recommend close observation of predatory birds and corvids during vantage point watches, in the proximity to potential or known Merlin sites during the breeding season, to aid identification of occupied territories and nesting locations. Merlin territorial behaviour, including aggressive defence of the nesting area from a range of species including corvids, herons and other raptors, can be useful in locating occupied territories and nest sites (Lusby *et al.,* 2011; Hardey *et al.*, 2009). There was one mobbing event recorded during vantage point watches, which was a male Merlin mobbing a Kestrel, which shows that this behaviour is useful in detecting Merlin. In addition, one other pair outside the survey area, in the Derryveagh and Glendowan Mountains SPA were recorded, when both adults were observed mobbing a Raven. Lusby *et al*. (2011) assessed Merlin mobbing behaviour and rates at known nest locations in Connemara and Donegal and showed that only 12.5% of potential mobbing events resulted in a response by breeding Merlin. Similar to other established techniques used for locating Merlin, negative results from potential mobbing events do not guarantee absence of Merlin.

There was not a significant investment in sign searching in this survey, and this technique was employed secondary to vantage point watches. The 2010 Pilot Merlin Survey identified the unreliability of sign searching for determining occupancy and for locating nests in certain situations (Lusby *et al*., 2011). Norriss *et al*. (2010) also highlighted the unreliability of sign searching, particularly for pairs at disturbed sites, or sites bordering grassland, as plucking tended to be carried out in the tree canopy. Without the aid of signs to narrow the search area, Norriss *et al*. (2010) reported that survey efficiency reduced from 87% to 60%. Lusby *et al*. (2011) reported that in the Irish uplands, sign-searching is a beneficial survey tool for locating certain pairs, but for other pairs this method is significantly less effective. This informed the decision to restrict sign-searching to within 300 m of potentially suitable breeding habitat in the current survey. Signs which were suspected to be of Merlin were recorded in eight survey squares, of which six were classed as occupied based on observations. There was a single sign recorded in two survey squares where there were no observations of Merlin recorded, however this information was not enough to classify these squares as ‘occupied’. The presence

of signs therefore did not result in determining occupancy or breeding status in any survey squares and the presence of signs did not assist in determining the location of Merlin nests. One of the limitations with this technique, is that it is often not possible to attribute signs to a specific species with confidence. Further assessment of the merits of sign searching, and how this technique may be best applied based on the landscape conditions would be useful, so that this technique could be targeted to the areas where it is most valuable and not employed in areas where its use is less effective. In this regard, survey guidelines specific to Merlin in the Irish context would be beneficial. Such guidelines would help to standardise monitoring efforts and improve survey standards, planning and resource allocation to Merlin surveys.

Nest searching was the most profitable technique in terms of the time invested and the number of pairs located by this method, albeit this was notably site-specific and cannot be used effectively in every circumstance. There was more than seven times the time investment in vantage point watches compared to nest searching, yet over half of the breeding pairs within the survey area were located via nest searches. All of the nests located were within the Connemara Bog Complex SPA. This emphasises the variability in the conditions and Merlin nest site choice in different areas of their breeding range in Ireland, and the fact that survey methods should cater to the site-specific conditions where they are most suited. In addition to being less time consuming, nest searches, where this is the most suitable technique, also provides greater confidence in the results compared to vantage point watches, which almost invariably provide limited information requiring some degree of interpretation. Therefore, the breeding densities recorded in the Connemara Bog SPA can be viewed with confidence and greater reliability. This technique is particularly suited to the Connemara landscape and is not as suited to other areas, at least in the breeding Merlin SPAs, though its application to other open landscapes should be considered.

It is clear that landscapes with high forest cover and particularly a high occurrence of forest edge, are the most difficult to survey for Merlin, despite the propensity for Merlin to nest in forest edges (Lusby *et al*., 2017). These areas require the most time and the highest number of vantage point locations, while at the same time providing the least confidence in the results, particularly where Merlin are not detected. It is clear from the findings of the current survey that the challenges of surveying Merlin in these environments can be lessened through a range of measures, such as targeted survey stratification. However, locating Merlin in forest-dominated landscapes will remain a significant challenge affecting both the ease of future surveys and the ability to detect the species for conservation purposes. For this reason, it is recommended that a range of alternative methods for detecting breeding Merlin are assessed. A drone with thermal sensor was used to survey for Merlin in the Connemara Bog Complex SPA and the surrounding area in 2022 and was successful in detecting nest sites (John Lusby, personal communication), however further work is needed to determine the level of confidence that can be placed in these survey methods.

5.3 Merlin occupancy and breeding densities

This study provides the first estimates of breeding densities of Merlin in the breeding Merlin SPA network, and allows for comparisons with other Merlin populations, to assess the suitability of the breeding Merlin SPAs for the species. Norriss *et al*. (2010) recorded 1.2 - 5.9 pairs per 100 km^2 in five study areas in Ireland. When these figures were interrogated, based on the survey area and the number of pairs recorded over the six years of the study, this equated to an average breeding density of 2.8 pairs per 100 km^2. Though slightly higher than the maximum estimate of pairs in our study, the estimate is lower than the breeding densities recorded in the Connemara Bog Complex SPA (*i.e*. 3.1 – 3.6 pairs per 100 km^2). Rebecca & Bainbridge (1998) reported mean densities of 0.25 to 2.67 pairs per 100 km^2 in randomly selected 10 km squares in nine regions of Britain during the 1993-1994 Merlin survey. Bibby & Nattrass (1986) concluded breeding densities were as high as 5 – 10 pairs per 100 km^2 in areas of suitable habitat, but these were rarely extensive and they quoted a value of 1.7 – 2.2 pairs per 100 km^2 for the Central Highlands of Scotland, which is similar to the Merlin breeding densities recorded in and surrounding the breeding Merlin SPA network in Ireland. Nattrass *et*

al. (1993), recorded 2.3 pairs per 100 km^2 in moorland of the north of England, again similar to estimates for the breeding Merlin SPAs. In other parts of Britain, where monitoring studies have been conducted in areas considered to be prime Merlin habitat, breeding densities reported have typically been higher than recorded in the current study. Newton *et al.* (1978) calculated densities of 3 - 13 pairs per 100 km^2 in Northumberland, with a mean density of approximately eight pairs per 100 km^2. Wright (1997) estimated a density of 12 pairs per 100 km^2 between 1983-1994 on moorland in North Yorkshire. Roberts & Jones (1999) found a density of five pairs per 100 km^2 between 1983 and 1997 in Wales. Therefore, breeding densities recorded in this study, are similar or within the range of breeding densities in Britain, determined by surveys that applied a random sampling approach, but are generally lower than reported breeding densities for areas considered to be 'prime' Merlin habitat.

The mean distance between pairs in the Connemara Bog Complex SPA is similar to previous estimates for Merlin in Ireland. Norriss *et al.* (2010) recorded the mean nearest neighbour distance, which ranged between 2.72 to 5.86 km in five areas where Merlin populations were assessed. Wright (1997) recorded a mean distance of 1.43 km between nesting pairs in North Yorkshire and Newton *et al.* (1978) noted annual inter-nest distances of 1.0 – 1.6 km apart in Northumberland. In the Connemara Bog Complex SPA, the availability of nesting sites does not seem to be a factor which is limiting the population, as there are many more islands with available stick nests than there are Merlin pairs. Merlin can also nest on the ground in dense vegetation on these islands (Dermot Breen, personal communication; Haworth, 1985). The greater distance between pairs in the Connemara Bog Complex compared to areas with high densities in Britain may be a reflection of low prey availability or other factors, which requires further investigation.

5.4 Population estimates

The Merlin population within the six SPAs is estimated to be between 27.5 to 41 breeding pairs, based on the number of confirmed and possible pairs recorded within the portion of the breeding Merlin SPA network surveyed, and extrapolated to the six SPAs. This is the first such estimate generated for Merlin within the breeding Merlin SPA network based on strategic survey effort. These estimates are comparable to previous estimates of 37 to 46 breeding pairs in the breeding Merlin SPA network reported under Article 12 for the period 2008-2012, which was based on partial data with some extrapolation and expert opinion. Given the uncertainty over previous estimates it is not possible to determine robust trends for the population in the breeding Merlin SPA network. However, our estimates now provide the basis for future comparisons and assessment of trends, provided the limitations of the survey are taken into consideration. The primary limitation with regards the Merlin population estimates is the fact that it was not possible to conduct the survey across the extent of the breeding Merlin SPA network, but rather it was focused on a sampled portion of the SPAs from which Merlin data within was extrapolated to derive an SPA wide estimate of numbers. It is hoped that as the knowledge base, of both Merlin in the SPAs and the survey methods, is expanded and refined, that a complete survey of the breeding Merlin SPA network (or individual SPAs over a phased basis) would be possible. This would provide a more robust population estimate. It should also be noted that the population estimates for the SPA network were lower than the population estimates for the wider survey area, which is due to the fact that there were more Merlin recorded in lands bordering the SPAs than inside the SPAs, based on the survey area covered. The population estimate for the breeding Merlin SPAs is based on breeding pairs which nest within the SPAs and does not take account of the breeding pairs which nest outside and in close proximity to the SPAs and are undoubtedly associated with and potentially dependent on the breeding Merlin SPAs. Taking this close association into consideration would be of relevance in considering management actions for, and monitoring of, Merlin in future.

5.5 Breeding performance and habitat selection

The breeding performance of Merlin in the breeding Merlin SPA network was higher than reported for most Merlin populations in Ireland and Britain. This included a higher breeding success rate than recorded for 300 breeding attempts between 1982 and 2014 for Merlin populations in eight study areas in Ireland (Lusby *et al.,* 2017). This breeding success is also higher than reported for all Merlin populations studied in Britain over the past 60 years for which data is compared (Table 6.). Failed breeding attempts for Merlin can be difficult to detect (Lusby *et al*., 2011, 2017; Newton *et al*., 1978; Norriss *et al*., 2010). This is indicated by the fact that one pair in Lough Nillan Bog SPA was recorded in courtship behaviour early in the season but was not recorded again after mid-April. The timing of survey visits is important in this regard and the majority of areas of potentially suitable breeding habitat in the survey squares were checked in April, in order to reduce the risk of missing any breeding pairs that failed early. In the Connemara Bog Complex SPA however, it was not possible to visit all islands early in the season, and it is feasible that early failed breeders may have been missed. In terms of comparisons to other populations, the potential to under-record failed breeding attempts likely affects all studies on Merlin (Newton *et al.,* 1978; Lusby *et al.,* 2011). The fledging success and productivity of Merlin, in and surrounding the breeding Merlin SPA network, also indicates good breeding performance when compared to other populations. However, caveats include the low sample size and thus caution should be applied to the interpretation of these figures. The fledging success of Merlin in this study was higher than reported for most Merlin populations, and the recorded productivity of Merlin in the SPAs was higher than for all other studies assessed (Appendix 4). The recorded productivity rate of 3.1 young for Merlin in and surrounding the breeding Merlin SPA network was above the published estimates of 2.5 young (Brown, 1976; Olsson, 1980) and 2.6 young per pair (Bibby, 1986) which have been cited as the levels required to sustain Merlin populations. However, productivity levels required to sustain populations vary between regions according to local survival, rates of emigration and immigration, and population densities. Little & Davidson (1992) recorded a Merlin population increase in Northumberland during a period when a productivity of less than 2.5 young per pair was recorded, while a population regarded as stable in northeast Scotland produced less than 2.2 young per pair (Rebecca *et al*., 1992). The observed productivity estimates for Merlin previously reported in Irish studies and this survey, and the fact that trends in breeding parameters appear to have remained constant over the past three decades (Lusby *et al*., 2017), suggests that the ability of the species to reproduce is not limiting the population in Ireland.

All located pairs in this study nested in trees, which supports previous evidence that ground nesting is now rare in Ireland, and that Merlin predominantly nest in trees (Lusby *et al*., 2017). The nest site selection of Merlin populations previously assessed in eight regions of Ireland showed that conifer plantation was the most important nesting habitat (Lusby *et al*., 2017). There was, however, only a single nest recorded in conifer plantation in the current survey (in Derryveagh and Glendowan Mountains SPA). The low occurrence of nests in planted forest in this survey is likely influenced by the difficulty in locating nests in forests. In both the Slieve Aughty Mountains SPA and the Wicklow Mountains SPA, where breeding activity was confirmed but nests not located, it was strongly suspected that the pairs nested in conifer plantations. Two nests were located in small copses (conifers), both of which surrounded houses, one a derelict farmhouse at the edge of Lough Nillan Bog SPA and the other surrounding an occupied house located just over 300 m from the Derryveagh and Glendowan Mountains SPA boundary. Lusby *et al*. (2017) showed that Merlin require open habitats for foraging within breeding territories, however they also require trees with suitable stick nests (where other nest sites such as in the form of deep heather, is not available). These are often the old nests of Hooded Crow (*Corvus cornix*) but nests of other species can also be used. Although there is extensive suitable foraging habitat throughout the breeding Merlin SPA network, in certain parts, nesting opportunities are apparently limited and confined to the planted forest bordering an SPA. This study indicated that planted forest is likely to provide important nesting sites to support the SPA populations, based on the number of breeding pairs and occupied territories recorded, with proportionally more located outside the SPA. From a

conservation perspective this may have implications for the protection of nest sites from forest management activities and highlights the need for careful assessment of risks prior to forest operations commencing within or close to an SPA. The Forest Service of the Department of Agriculture, Food and the Marine (FS-DAFM) recently introduced measures which restrict forest management within 100 m of the edge of forest edge during the nesting season to reduce disturbance to breeding Merlin. However, these measures are only implemented within the breeding Merlin SPA network and do not afford protection to pairs nesting adjacent to and outside the SPA. It is clear that these measures need to be reviewed in light of the survey findings.

The most common nest site choice of Merlin recorded in this study were in stick nests in trees, on small wooded islands on lakes, all of which were in the Connemara Bog Complex SPA. This nest site choice was also the primary nest site type recorded in Connemara in previous studies (Haworth, 1985; Haworth, 1986; Lusby *et al*., 2017). Due to the isolated nature and accessibility of these islands, they are likely to change little and are not under threat from land clearance, overgrazing or burning. These sites should remain suitable for Merlin into the future, as is shown by the fact that some of the islands which were located by Haworth (1986) in the mid-1980s have been used in recent years (Dermot Breen, personal communication).

Figure 7 Merlin nest in a tree on a wooded island in Connemara. Photograph © Dermot Breen.

6 Recommendations

6.1 Merlin surveys

6.1.1 Future survey and monitoring

This was the most extensive survey of breeding Merlin in Ireland and provides information on the population size and breeding densities of Merlin in the SPAsfor the first time, against which future changes in the population can be assessed. This survey also demonstrated that a large-scale survey undertaken by an extensive network of trained surveyors and volunteers can obtain reliable data on the presence and distribution of the species. It is important to build on this momentum and to capitalise on the increased surveyor base and enhanced capacity to census the species. In this regard, this survey is but a starting point to improving our understanding of Merlin within the breeding Merlin SPA network and in the wider countryside. Despite the advances in our understanding of Merlin breeding in SPAs, there remain significant knowledge gaps in the national context. The resources allocated to Merlin surveys in the future should reflect these knowledge gaps as well as the challenges associated with surveying the species. We recommend that a defined schedule for Merlin surveys in the breeding Merlin SPA network is established, alongside targeted monitoring in areas outside the SPA network, to address these remaining knowledge gaps.

Ideally, Merlin surveys, conducted every five years, within the breeding Merlin SPA network, would ensure information is available for conservation purposes in any reasonable given period. The benefits of this proposed schedule include:

- achieving a better understanding of Merlin populations in the breeding Merlin SPA network,
- facilitation of efficient conservation planning,
- maintaining and enhancing the surveyor base and
- ensuring effective reporting on Merlin populations to meet the requirements under Article 12.

Subsequent Merlin surveys in the breeding Merlin SPA network should follow a consistent approach as described here, refined where needed to cater for advances and/or developments in survey techniques. To ensure that the collection and collation of data and reporting of breeding records is standardised, and to allow for comparisons between surveys, a database template should be designed and used for all future surveys. As knowledge of Merlin in the breeding Merlin SPAs increases, alongside the experienced surveyor base, it should be possible to expand the size of the survey area with each subsequent survey and ultimately seek to achieve full coverage of the breeding Merlin SPA network.

Merlin surveys in the breeding Merlin SPA network carried out to a defined schedule will provide more up-to-date information on current population sizes and trends and help inform management of the SPAs for the species. However, there remain significant gaps in our understanding of the distribution of the species outside of the breeding Merlin SPA network, and therefore overall national population size estimates and trends. For example, the suitability and importance for Merlin of large swathes of raised bogs in midland counties. The Bird Atlas of 2007 – 2011 shows a strong bias in distribution of breeding Merlin towards the northern half of the island (Balmer *et al*., 2013), with only 6% of the 10 km squares which held confirmed breeding records for Merlin (n = 50) located in Munster. It is not known if the distribution of breeding Merlin as reported by the Bird Atlas 2207 – 11 is influenced by observer effort or if it accurately reflects the distribution of the breeding population. Bioclimatic models predict that the breeding range of Merlin in Europe will shift substantially northwards due to climate change, and therefore the distribution of Merlin will retreat from much of the currently occupied range in Ireland and Britain (Huntley *et al*., 2007). The breeding productivity of Merlin was also higher at more northerly latitudes over the period 1982 to 2014 (Lusby *et al*., 2017). It is recommended

that an annual monitoring programme is established to determine Merlin breeding densities, population size and breeding parameters in selected areas both within and outside the breeding Merlin SPA network. This approach would require significantly less resources than undertaking a national survey, would provide greater confidence in the data generated and would complement the recommended quinquennial surveys. Regional monitoring studies on Merlin have been proven to be effective and have provided the primary sources of information on Merlin breeding ecology and status to date (Lusby *et al*., 2017; Norriss *et al*., 2010). The annual monitoring programme should aim to generate data on Merlin breeding performance, population size and ecology within defined survey areas where there is currently a lack of information on breeding Merlin (primarily blanket and raised bogs). This would allow assessment of the importance of these areas for Merlin in the context of the breeding Merlin SPAs and further inform habitat suitability for breeding Merlin. it would assist in assessing the distribution and size of the national population, and aid future national survey effort.

6.1.2 Improving survey standards for breeding Merlin

The challenges and time investment required to effectively census breeding Merlin were demonstrated by this survey. Despite the significant time investment on behalf of experienced surveyors, employing specialised techniques, the field observation rates of Merlin were extremely low. These findings indicate that there is the potential for Merlin to be overlooked on surveys that do not employ the same techniques or time investment. This is a concern if, for example, breeding Merlin are not detected by surveys to inform Environmental Impact Assessments (EIAs), or forest management activities, as the ability to identify and mitigate potential disturbance events on breeding Merlin is compromised. The establishment of defined survey standards for breeding Merlin in Ireland is recommended. This would include the criteria required in the planning, resource allocation, implementation and reporting of Merlin surveys, to ensure that surveys are carried out according to best practice standards.

6.1.3 Improving survey efficiency

Merlin predominantly nest in open landscapes which are associated with a high proportion of forest cover in Ireland, and select conifer plantations for nesting (Lusby *et al*., 2017). Merlin surveys in areas with extensive forest cover are challenging and demanding of resources. Such landscapes affect the ability to undertake future surveys and to detect the species for conservation purposes. We recommend the further testing of alternative survey techniques to detect breeding Merlin and improving survey efficiency. In particular, we recommend that structured trials are undertaken to assess the ability of a drone with thermal sensor to detect breeding Merlin and the confidence that can be placed in this survey approach.

6.2 Conservation and management

6.2.1 Review of forest management measures to protect breeding Merlin

The risk of disturbance to breeding Merlin from forest management activities has been previously highlighted (Lusby *et al*., 2017). Measures intended to protect forest nesting Merlin were introduced by the Forest Service in 2020, which restrict felling, thinning or other forestry operations during the period 1 March to 31 August within 100 metres of the forest edge, which is immediately adjacent to moors, heathland, peat bogs or natural grassland, or within 100 metres of a clearing in the forest of larger than one hectare. These measures represent an important first step to reducing the risk and effects of disturbance from forest management activities on breeding Merlin, however the effectiveness of these measures have not yet been evaluated. In addition, these measures only apply to and afford protection to, Merlin within the breeding Merlin SPA network. The distribution of breeding Merlin in the wider countryside and the importance of undesignated areas remains largely unknown. The findings of this survey highlight the importance of lands bordering the breeding Merlin SPA network, with a higher density of Merlin pairs recorded in lands adjacent to the SPA compared to within the SPA.

Although there is extensive suitable foraging habitat throughout the breeding Merlin SPAs, in certain parts, nesting opportunities are limited and are confined to the planted forest bordering the SPA. We recommend that the measures to protect breeding Merlin from forest management activities are reviewed and refined, to deliver the appropriate protection to breeding Merlin in all situations.

6.2.2 Review of the impacts of afforestation on breeding Merlin

Although breeding Merlin selected conifer forests at the nest site scale, their use or avoidance of this habitat for foraging is not known. In Ireland, given the limited availability of suitable quality habitats for ground nesting, at least in certain parts of their range, afforestation may have allowed Merlin to exploit nesting opportunities in areas with open suitable foraging habitat, but where preferred ground nesting options are limited (*e.g*. on heath/blanket bog). However, once suitable nest sites are available, the extent of forest cover may subsequently have a negative effect on Merlin, as has been reported for some Merlin populations in Britain (Newton *et al*., 1978; Orchel, 1992; Rebecca, 2006). Lusby *et al*. (2017) showed that of 343 breeding Merlin territories assessed, there was an average forest cover of 11% within 5 km of nests, which did not exceed 35% of the land cover surrounding nests. This may suggest that areas with more extensive forest cover may be less suitable for breeding purposes; however, more rigorous sampling in different landscape conditions is required to understand Merlin distribution and habitat suitability and to inform conservation management. Equally, the application of modern tracking techniques to study Merlin movements and breeding and foraging ecology may elucidate valuable information to inform conservation and management, and such studies should be encouraged where feasible.

6.2.3 Conservation objectives for Merlin SPAs

Article 4(4) of the Habitats Directive 92/43/EEC requires that all sites submitted to the Commission must have established priorities for the maintenance or restoration of those sites (Conservation Objectives) at a favourable conservation condition. Conservation Objectives are important components in developing an effective conservation strategy for a given habitat or species and would have several tangible benefits for the management of Merlin SPAs. These would include defining measurable objectives required to achieve favourable conservation condition, providing transparency to stakeholders as to the performance of the breeding Merlin SPA network and allowing the performance of these SPAs to be determined on an on-going basis that would facilitate effective reporting (*e.g*. Article 12), conservation planning and implementation of conservation measures on a site-specific basis. Favourable Reference Values (FRVs) are functional thresholds for assessing and reporting the conservation status.

7 Bibliography & Relevant Literature

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

Bibby, C.J. & Nattrass, M. (1986). Breeding status of the Merlin in Britain. *British Birds* **79**, 170–185.

BirdWatch Ireland. (2011). Action Plan for Upland Birds in Ireland 2011-2020. BirdWatch Ireland's Group Action Plans for Irish Birds. BirdWatch Ireland, Kilcoole.

Bleasdale, A. (1998). Overgrazing in the West of Ireland – assessing solutions. In G. O'Leary & F. Gormley (eds). *Towards a Conservation Strategy for the Bogs of Ireland.* Irish Peatland Conservation Council, Dublin.

Cade, T.J. (1982). *The Falcons of the World.* Cornell University Press, London.

Ellis, P.M. & Okill, J.D. (1990). Breeding ecology of the Merlin *Falco columbarius* in Shetland. *Bird Study* **37**, 101–110.

Ewing, S.R., Rebecca, G.W., Heavisides, A., Court, I.R., Lindley, P., Ruddock, M., Cohen, S. and & Eaton, M.A. (2011). Breeding status of Merlins *Falco columbarius* in the UK in 2008. *Bird Study* **58**, 379-389.

Fernandez-Bellon, D., Carroll, D. & Lusby, J. (2010). The Pilot Merlin Survey 2010. BirdWatch Ireland Report.

Fernandez-Bellon, D. & Lusby, J. (2011). The feeding ecology of Merlin *Falco columbarius* during the breeding season in Ireland, and an assessment of current diet analysis methods. *Irish Birds* **9**, 159-164.

Fuller, R.J. & Gough, S.J. (1999). Changes in sheep numbers in Britain: implications for bird populations. *Biological Conservation* **91**, 73-89.

Gibbons, D.W., Reid, J.B. & Chapman, R.A. (1993). *The New Atlas of Breeding Birds in Britain and Ireland: 1988-1991*. Poyser, London.

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

Hardey, J., Crick, H., Wernham, C., Riley, H., Etheridge, B. & Thompson, D. (2009). *Raptors: a field guide for surveys and monitoring.* Stationery Office, Edinburgh.

Haworth, P.F. (1985). A survey of upland breeding birds in west Galway, Éire. Report to the World Wildlife Fund Project.

Haworth, P.F. (1986). Survey of west Galway. Report to the World Wildlife Fund Project.

Hutchinson, C.D. (1989). *Birds in Ireland*. T. & A.D. Poyser.

Little, B. & Davison, M. (1992). Merlins *Falco columbarius* using crow nests in Kielder Forest, Northumbria. *Bird Study* **39**: 13–16.

Lusby, J., Férnandez-Bellon, D., Norriss, D.W., & Lauder, A. (2011). Assessing the effectiveness of monitoring methods for Merlin *Falco columbarius* in Ireland: the Pilot Merlin Survey 2010. *Irish Birds* **9**, 143 – 154.

Lusby, J., Corkery, I., McGuiness, S., Fernández-Bellon, D., Toal, L., Norriss, D.W., Breen, D., O'Donaill, A., Clarke, D., Irwin, S., Quinn, J.L., O'Halloran, J. (2017). Breeding ecology and habitat selection of Merlin *Falco columbarius* in forested landscapes, *Bird Study* **64**, 445-454.

Madden, B., Hunt, J, & Norriss, D.W. (2009). The 2002 survey of Peregrine *Falco peregrinus* breeding population in the Republic of Ireland. *Irish Birds* **8**, 543-548.

McElheron, A. (2005). *Merlins of the Wicklow Mountains.* Currach Press, Dublin.

Meek, E.R. (1988). The breeding ecology and decline of the Merlin *Falco columbarius* in Orkney, *Bird Study* **35**, 209-218.

Moran, P. & 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, Ireland.

Newton, I., Meek, E.R. and Little, B. (1978). Breeding ecology of the Merlin in Northumberland, *British Birds* **71**, 376-398.

Newton, I., Meek, E.R. & Little, B. (1986). Population and breeding of Northumbrian Merlins. *British Birds* **79**, 155–170.

Norriss, D.W., Haran, B., Hennigan, J., McElheron, A., McLaughlin, D.J., Swan, V. & Walsh, A. (2010). Breeding biology of Merlins *Falco columbarius* in Ireland, 1986-1992. *Irish Birds* **9**, 23-30.

NPWS (2019) Annex B – Bird species' status and trends report format (Article 12) for the period 2013–2018. Report to European Commission. Available at www.eionet.europa.eu.

Orchel, J. (1992). *Forest Merlins in Scotland; Their Requirements and Management: a Report on the Galloway Forests Merlin Project (1986-89).* Hawk and Owl Trust, London.

QGIS Development Team. (2018). QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org

Rebecca, G.W., Cosnette, B.L., Hardy, J.J.C. & Payne, A.G. (1992). Status, distribution and breeding biology of the Merlin in Northeast Scotland, 1980–1989. *Scottish Birds* **16**, 165–183.

Rebecca, G.W. (2006). The breeding ecology of the Merlin *Falco columbarius aesalon,* with particular reference to north-east Scotland and land-use change. PhD thesis, Open University.

Rebecca, G.W. (2011). Spatial and habitat-related influences on the breeding performance of Merlins in Britain, *British Birds* **104**, 202-216.

Rebecca, G.W. & Bainbridge, I.P. (1998). The breeding status of the Merlin *Falco columbarius* in Britain in 1993–94. *Bird Study* **45**, 172–187.

Roberts, J.L. & Green, D. (1983). Breeding failure and decline of Merlins on a north Wales moor. *Bird Study* **30**, 193–200.

Sale, R. (2015). *The Merlin*. Snowfinch Publishing, UK.

Sharrock, J.T.R. (1976). *The Atlas of Breeding Birds in Britain and Ireland.* British Trust for Ornithology, Hertfordshire.

Sieg, C.H. & Becker, D.M. (1990). Nest-site habitat selected by Merlins in south-eastern Montana. *The Condor* **92**, 688-694.

Staneva, A. & Burfield, I. (2017). European Birds of Conservation Concern: Populations, trends and national responsibilities. BirdLife International and Central Asian Partnership, Cambridge, U.K.

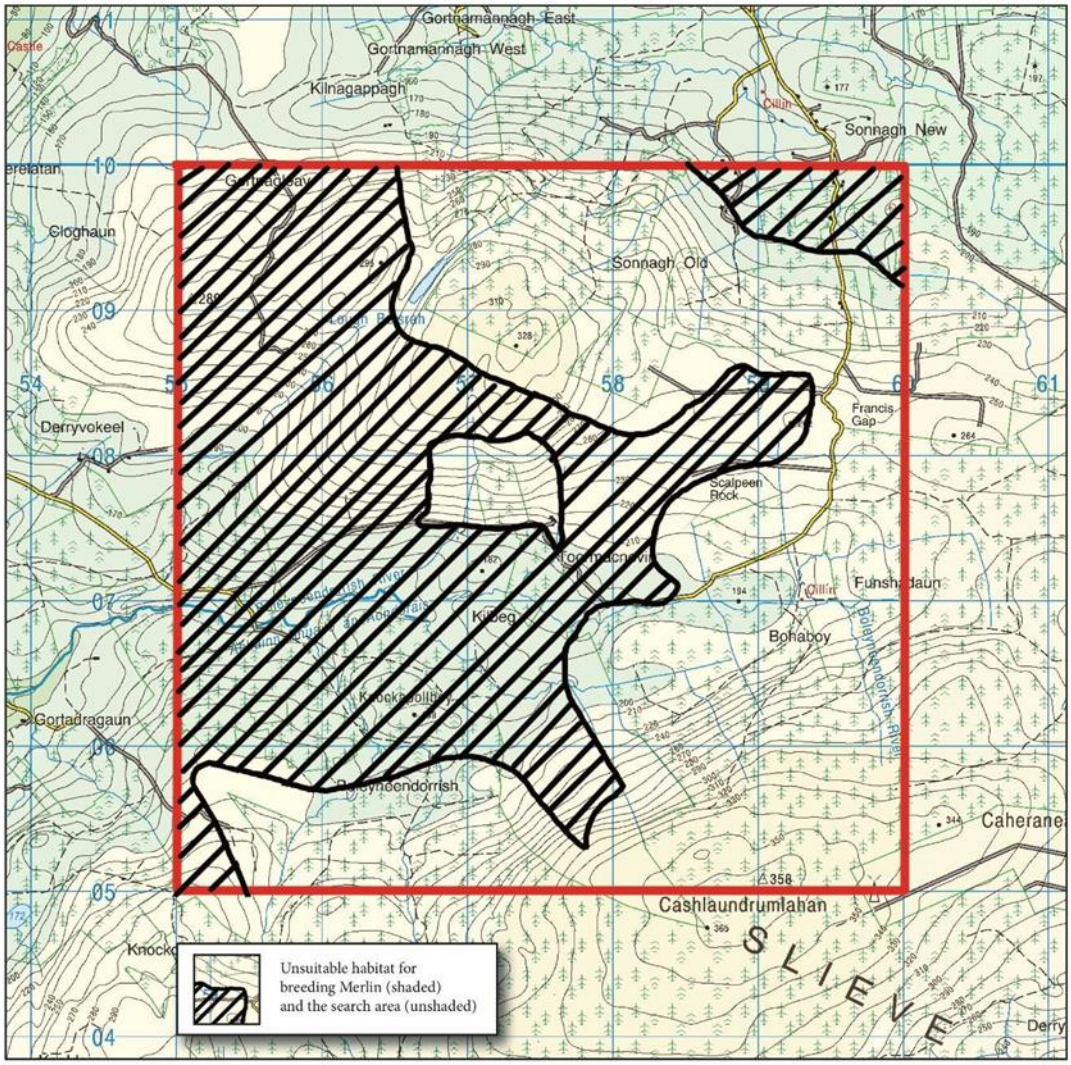
Wilson, M.W., O'Donoghue, B., O'Mahony, B., Cullen, C., O'Donoghue, T., Oliver, G., Ryan, B., Troake, P., Irwin, S., Kelly, T.C., Rotella, J.J. and & O'Halloran, J. (2012). Mismatches between breeding success and habitat preferences in Hen Harriers *Circus cyaneus* breeding in forested landscapes. *Ibis*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

Wright, P.M. (1997). Distribution, site occupancy and breeding success of the Merlin *Falco columbarius* on Barden Moor and Fell, North Yorkshire. *Bird Study* **44**, 182-193.

Appendix 1 Sample Field Map of 5 km x 5 km (Ordnance Survey Grid

Merlin Survey 2018
Sample map completed

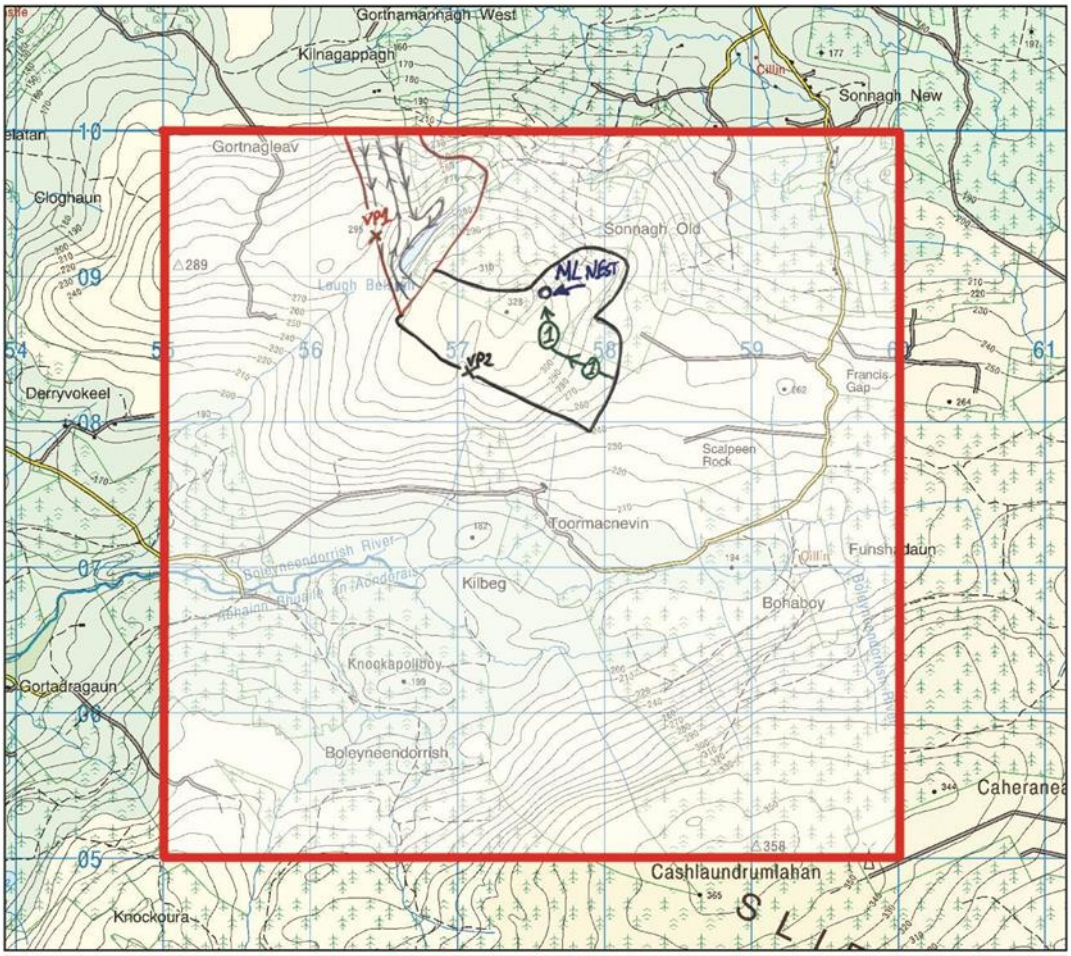
5km x 5km square



Survey square ID..... IM5505
Survey square name.....Toormacrevin
SPA name.....Slieve Aughties
Surveyor's name.....John Lusby

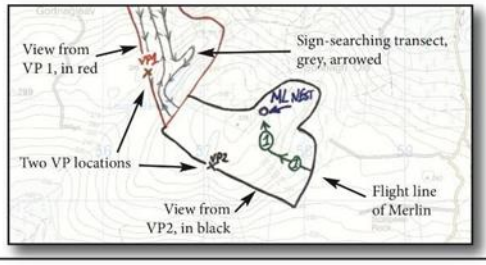
Merlin Survey 2018
Sample map completed

5km x 5km square



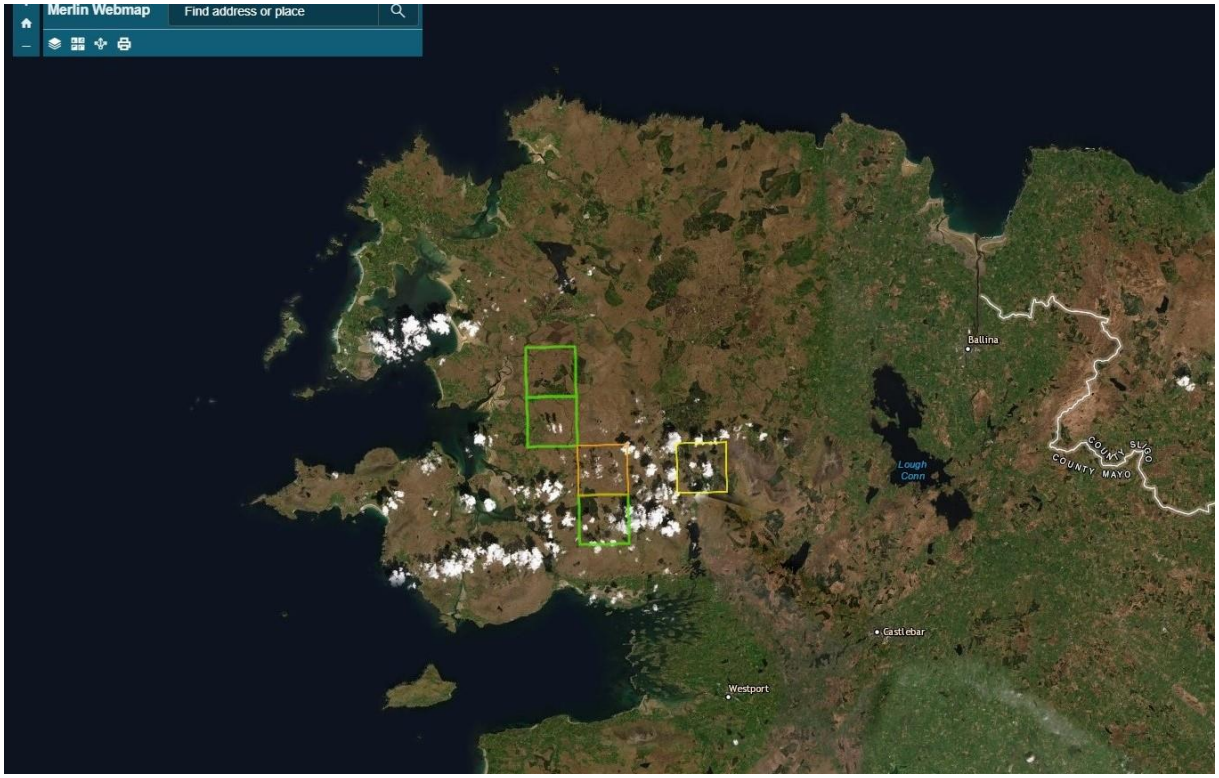
Survey square ID..... IM5505
Survey square name..... Toormacrevin
SPA name..... Slieve Aughties
Surveyor's name..... John Lusby

Date..... 03/05/2018
Visit number..... 2
Survey start time..... 06.10
Survey finish time..... 15.05



Key to map annotation
A map showing a typical survey day, with two VP locations, the views from these VP locations, location of Merlin nest, a flight line of Merlin, and sign-searching transects, as well as associated details for the square and survey visit below the main map.

Appendix 2 Sample of ArcGIS webmap



Appendix 3 Merlin 2018 Survey Sample Recording Form

Merlin Survey 2018

Date	SPA name		Survey Square ID	
Survey start time	Surveyor name		Visit no.	Page no.
Survey finish time	Survey square name		County	
Additional surveyor(s)	Visibility	Rain	Wind	Cloud

Using a separate recording form for each survey date, record the following information for each survey date.
Date – Date of survey visit in the form day.month.year, e.g. 01.04.2018
SPA Name – The name of the SPA in which the survey square is contained.
Survey Square ID – The 10km square which contains the 5 x 5km survey square and the associated position of the 5 x 5km survey square within the 10km square, i.e. 'IM02 NW'.
Survey start time – The start time of the survey, i.e. the time that you arrived on site and initiated survey, using 24hr clock, e.g. 07:10.
Surveyor name – Full name of lead surveyor.
Visit no. – The visit number 1 - 4.
Survey finish time – The finish time of the survey, i.e. the time you completed survey and departed from site, using 24hr clock, e.g. 20:25.
Survey Square Name – Townland, place name or feature to name the survey square.
County – The county in which the square is contained, for squares which fall in two counties use the county which the majority of that square is in.
Additional surveyor(s) – Full names of all other surveyors who took part in survey on this visit.
Visibility – distance of view recorded as an average for each Vantage Point Watch (0 - 2), 0 = poor visibility of <1km, 1 = moderate visibility of 1 - 3km & 2 = good visibility of >3km.
Rain – Rain conditions recorded as an average for each Vantage Point Watch (0 - 3), 0 = no rain, 1 = light showers, 2 = heavy showers & 3 = heavy rain.
Wind – Wind conditions recorded as an average for each Vantage Point Watch using four combined Beaufort categories (0 - 3), 0 = calm to light breeze, 1 = gentle to moderate breeze, 2 = fresh to strong breeze, 3 = moderate gale to gale.
Cloud – Cloud cover recorded as an average for each Vantage Point Watch expressed in oktas (0 - 8) with 0 being no cloud cover and 8 being full cover.

Vantage Point Watch

VP start time	VP finish time	Vantage Point no.

Encounter Log (Merlin and other key species)

Ref. No.	Encounter time	Encounter grid reference	Species	Sex	Age	Type	Behaviour code 1	Behaviour code 2	Behaviour code 3	Habitat code 1	Habitat code 2	Habitat code 3	Notes

VP start time – The start time of the Vantage Point Watch using the 24hr clock, e.g. 06:10.
VP finish time – the finish time of the Vantage Point Watch using the 24hr clock, e.g. 20:25.
Vantage Point no. – The assigned number of the Vantage Point Watch (VP) which should correspond to the annotated maps.
Ref. no. – The encounter number of a Merlin or other key species, which should correspond to the annotated map.
Encounter time – The initial time of encounter of the species using the 24hr clock.
Encounter grid reference – The location of the bird in Irish Grid to a 6-figure Grid reference.
Species – The species encountered using BTO codes, in addition to Merlin (ML), record key species including Curlew (CU), Golden Plover (GP), Dunlin (DN), Red Grouse (RG), Red-throated Diver (RH), Short-eared Owl (SE), Hen Harrier (HH), Peregrine Falcon (PE), Kestrel (K.), Sparrowhawk (SH), Buzzard (BZ), Whinchat (WC), Raven (RN), Hooded Crow (HC) and other (list species).
Sex – The sex of the bird if known, Male, Female or Unknown.
Age – The age of the bird if known, Adult, Juvenile, 2nd Summer or Unknown.
Type – The type of encounter, whether you recorded the bird by observation or vocalisation.
Behaviour codes – The behaviour of the bird using specific behaviour codes as follows, Display (D), Flying (F), Hunting (H), Perched (P), Plucking (PL), With Prey (WP), Prey Delivery (PD), Alarm (A), Mobbing (M), Attending nest (AN), Other (O).
Habitat codes – The habitat the bird is associated with according to the specific habitat codes as follows, Heather moorland/bog (H), Grass moorland (G), Rough Grassland (RG), Improved grassland (IG), Mature forest (MF), Young forest (YF), Scrub (S), Other trees or woodland (T).
Notes – Any notes relevant to the site visit or Vantage Point Watch.

Submitting Recording Forms: Please submit all data sheets by **17th August 2018**.

Paper or digital copies of this recording sheet should be posted to:
Merlin Survey, C/o John Lusby, 31 Gleann na Colle, Barna Road, Galway, Co. Galway.
or Merlin Survey, C/o Ryan Wilson-Parr, 78 Gleann Alainn, Tullyallen, Drogheda, Co. Louth.

or emailed to: jlusby@birdwatchireland.ie or monitoring@irsg.ie

An Roinn Cultúir, Oidhreachta agus Gaeltachta
Department of Culture, Heritage and the Gaeltacht

Irish Raptor Study Group

BirdWatchIreland

Merlin Survey 2018

Sign searching

Search start time | Search finish time

Sign No.	Perch grid reference (10 figure)	Perch type	Re-used	Species	Sign type	No. of species	Signs collected	Notes

Search start time – The time sign searching was initiated, using 24hr clock.
Search finish time – The time sign searching was initiated, using 24hr clock.
Sign no. – The number assigned to each plucking perch on which evidence or potential evidence of Merlin is recorded.
Perch grid Reference – The location recorded using the Irish Grid at 10-figure using a hand-held GPS unit (e.g. IM 5567805768) of the plucking perch.
Perch type – The type of perch, Hummock (H), Post (P), Boulder (B), Tree (T), Tree Stump (TS), Turf Pile (TF), Other (O).
Re-used – Whether there is previous evidence of the plucking perch being used by Merlin during the survey, i.e. was there prey remains recorded on the same perch on a previous visit, Y/N.
Species – The species responsible for the signs where known, using BTO codes for species.
Sign type – The type of sign/s recorded, which include Feathers (F), Avian remains (A), Moth wings (M), Frog (Fr), Small mammal (Sm), Lizard (L), Pellet/s (P), Moulted feathers of Merlin (MF), White-wash (W).
No. species – The number of individual prey items present on the plucking perch, estimate where exact number is not possible to discern.
Signs collected – Whether the signs were collected, Y/N.
Notes – Any notes relevant to the search.

Casual observations/ other species

Note: Observations of Merlin and other key species (listed below) which are not observed on VP watches (e.g. while sign-searching, recce of survey square, etc.).

Ref. No.	Encounter Time	Encounter Grid reference	Species	Sex	Age	Type	Behaviour 1	Behaviour 2	Behaviour 3	Habitat 1	Habitat 2	Habitat 3	Notes

Ref. no. – The encounter number of a Merlin or other key species, which should correspond to the annotated map.
Encounter time – The initial time of encounter of the species using the 24hr clock.
Encounter grid reference – The location of the bird in Irish Grid to a 6-figure Grid ref
Species – The species encountered using BTO codes, in addition to Merlin (ML), record key species including Curlew (CU), Golden Plover (GP), Dunlin (DN), Red Grouse (RG), Red-throated Diver (RH), Short-eared Owl (SE), Hen Harrier (HH), Peregrine Falcon (PE), Kestrel (K.), Sparrowhawk (SH), Buzzard (BZ), Whinchat (WC), Raven (RN), Hooded Crow (HC) and other (list species).
Sex – The sex of the bird if known, Male, Female or Unknown.
Age – The age of the bird if known, Adult, Juvenile, 2nd Summer or Unknown.
Encounter Type – The type of encounter, whether you recorded the bird by observation or vocalisation.
Behaviour codes – The behaviour of the bird using specific behaviour codes as follows: Display (D), Flying (F), Hunting (H), Perched (P), Plucking (PL), With Prey (WP), Prey Delivery (PD), Alarm (A), Mobbing (M), Attending nest (AN), Other (O).
Habitat codes – The habitat the bird is associated with according to the specific habitat codes as follows: Heather moorland/bog (H), Grass moorland (G), Rough Grassland (RG), Improved grassland (IG), Mature forest (MF), Young forest (YF), Scrub (S), Other trees or woodland (T).
Notes – Any notes relevant to the casual observation.

Appendix 4 Merlin breeding parameters in Ireland and Britain

Location	Years	Breeding success	No. sites	Fledged / successful attempt	No. sites	Productivity	No. sites
SPA network (this study)	**2018**	**87.5%**	**8**	**3.5**	**7**	**3.1**	**8**
Ireland[a]	1982-2014	74%	300	3	188	2.1	265
Orkney[b]	1981-1987	44%	61	2.8	61	1.3	61
Wales[c]	1975-1982	43%	42	3.5-3.8	42	-	-
NE Scotland[d]	1980-1989	65.5%	328	3.5	166	2.2	232
Shetland[e]	1984-1987	71%	86	3.4	61	2.4	86
Yorkshire[f]	1983-1994	85%	82	3.4	82	2.9	82
Northumbria[g]	1961-1976	65-66%	182	3.6	182	2.3	182
Northumbria[h]	1974-1983	-	275	3.3	275	1.9	275
Britain[i]	1983-1984	65%	498	3.4	498	2.2	498
Britain[j]	1993	-	450	3.1	292	2.0	450
Britain[j]	1994	-	451	3.5	324	2.5	451

[a]Lusby *et al*. (2017); [b]Meek (1998); [c]Roberts & Green (1983); [d]Rebecca *et al*. (1992); [e]Ellis & Okill (1990); [f]Wright (1997); [g]Newton *et al*. (1978); [h]Newton *et al*. (1986); [i]Bibby & Nattrass (1986); [j]Rebecca (2011).

npws.ie

National Parks and Wildlife Service

Rialtas na hÉireann
Government of Ireland