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The 2015 National Survey of Breeding Hen Harrier in Ireland

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The 2015 National Survey of Breeding Hen Harrier in Ireland

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Golden Eagle Trust, Irish Raptor Study Group & BirdWatch Ireland

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Contents

Executive Summary

The hen harrier (*Circus cyaneus*) is a protected raptor, listed in Annex I of the EU Birds Directive and as such, Member States are obligated to protect and conserve the species. These obligations involves key actions to designate Natura 2000 sites, also known as Special Protection Areas (SPAs) and also to undertake monitoring of hen harriers nationally, regionally and within the designated areas. The fourth national survey of hen harriers in Ireland was undertaken in 2015 and was preceded by surveys in 2010; 2005 and 1998-2000. Similar to previous surveys the aims were to quantify the size and distribution of the breeding population and examine changes since the previous national surveys. The survey effort and participation increased since 2010 with more than 7000 hours observational effort undertaken by 259 fieldworkers, largely via volunteer networks.

In 2015, an estimated 108 – 157 breeding pairs of hen harrier were recorded. This is lower than the population estimates in 2010 (128 – 172); similar to the estimate in 2005 (132 – 153) and marginally higher than the population 1998 – 2000 (102 – 129). This represents a decline of 15.6% in the number of confirmed breeding pairs since 2010 and an 11.4% increase in the number of possible pairs. The distribution of the confirmed breeding population was similar to 2010 with 62 10km squares occupied, however, overall breeding distribution (including confirmed and possible pairs) of the population has increased by 22% to 84 10km squares compared to 69 10km squares in 2010. This may in part be due to increased survey effort and/or the increasing number of possible breeding pairs.

In order to minimise biases of increasing survey effort within population estimates a series of subset analyses were undertaken along with calculating an estimate of the mid-point metric also to reduce survey effort bias between national surveys. The national population (confirmed and possible pairs) has declined by 8.7% since 2010 whilst mid-point analysis indicated a national decline of 11.7% since 2010. Analysis of 139 10km squares surveyed in both 2015 and 2010 estimates a population decline of 16.4%. Analysis of 110 squares surveyed in 2015; 2010 and 2005 estimates a decline of 9.7% between 2005 and 2015. Analysis of 78 squares covered in all four national surveys estimates an overall decline of 33.5% between 1998 – 2000 and 2015. Observers recorded useful metrics on pressures in hen harrier breeding areas to help inform current environmental conditions for breeding hen harriers.

Some regional areas have declined and others increased which may be at least partly explained by the redistribution of pairs and/or increased survey effort. The SPAs held between 44% and 47% of the national population (51 – 69 pairs) with four SPAs recorded to decline and two which have increased since 2005. Overall the population of hen harriers within the SPA network has declined by 26.6% since 2005. Hen harriers in this breeding survey were most frequently recorded to forage in open non-afforested habitats (51.3%) compared to afforested habitats (40.6%) but recorded more frequently to nest in second rotation forest (59.3%) than heather moorland (25.9%). Breeding success was higher per

confirmed breeding pair (45.4%) than recorded in other studies but productivity was low (0.94 young per confirmed breeding pair) compared to published studies. This survey report should inform further spatial analysis to inform management to optimise the environmental conditions for the breeding population of hen harriers in Ireland.

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1.0 Introduction

Raptors are widely recognised as effective biological and biodiversity indicators and as top predators which are vital for ecosystem functioning (Finke & Denno, 2004; Sergio *et al*., 2005a; b; 2006 Gomez-Ramirez *et al*., 2014). Monitoring provides information to diagnose population trajectories, and facilitate assessment of environmental change and/or threats which is necessary to inform conservation status and management. Fundamentally, monitoring is required for the evaluation of the conservation status of a population, assessment of biological responses to environmental change (e.g. land-use, climate change, habitat fragmentation, persecution, pollution etc.), and to inform responses for conservation and wider policy (Schmeller *et al*., 2012).

Hen harrier distribution and abundance has varied historically in Ireland (see O'Donoghue, 2010, O'Donoghue *et al.,* 2011 Ruddock *et al*., 2012; NPWS, 2015 for reviews). The most recent Bird Atlas (2007-2011) recorded hen harriers in 142 10km squares on the island of Ireland (Balmer *et al*., 2013) which represents a 16% decrease from the 169 10km squares in the first Atlas (Sharrock, 1976). There was a recorded 46% increase from 97 10km squares from the 1988-91 Breeding Atlas (Gibbons *et al*., 1993), however the Bird Atlas (2007-2011) coincided with increased survey efforts through the 2010 national survey (Ruddock *et al*., 2012). The hen harrier has long been a species of conservation concern in Ireland and the UK (Newton *et al.,* 1999; Gregory *et al*., 2002; Lynas *et al*., 2007; Eaton *et al*., 2009; Colhoun & Cummins, 2013) and is protected nationally under The Wildlife Act 1976 & Amendment Act 2000. Hen harriers are listed on Annex I of the Birds Directive (2009/147/EEC) and classed as amber-listed in the *Birds of Conservation Concern in Ireland* (BOCCI; Colhoun & Cummins, 2013).

The EU Birds Directive provides a legislative framework for the conservation of the hen harrier population which includes the requirement for monitoring, research and the designation of Special Protection Areas (SPAs). Under the Birds Directive Member States are required to maintain the Irish hen harrier population (Article 2); preserve, maintain and/or re-establish a sufficient diversity of areas and habitats (Article 3 & Article 4); encourage necessary research and scientific 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). The Birds Directive thus provides a statutory and legislative basis for national surveys and conservation strategies by creating a requirement to monitor and conserve the hen harrier population.

In the Article 12 analysis and reporting for the hen harrier in Ireland (NPWS, 2012; NPWS, 2015) the species is listed as moderately declining in Ireland as a breeding species within both long-term (1972 – 2010) and short-term (2000 – 2010) trends. The wintering population is described as moderately

declining both in the short-term and the long-term (see also NPWS, 2012). A Hen Harrier Threat Response Plan (HHTRP) in preparation by NPWS (see Moran & Wilson-Parr, 2014; NPWS, 2015) aims to set out a framework of measures required to ensure the conservation of the hen harrier in Ireland.

Fundamental to establishing population status, distribution and change is the requirement for surveys of breeding areas to incorporate all suitable habitats and not just those locations where the species has occurred historically, since some habitats (notably plantation forests) may change over time. The core aim of this study is to provide data for an updated assessment of the population status of the hen harrier in Ireland and compare this to estimates from previous national surveys (1998 – 2000; 2005 & 2010). Specifically this requires an examination of the breeding range(s) and suitable breeding habitat in which hen harriers can occur in Ireland. This requires regional and national data on spatial occurrence and analysis of spatial data, to examine regional and/or national spatial and temporal changes.

1.1 Surveys of the hen harrier in Ireland

The first national hen harrier survey in the Republic of Ireland was undertaken between 1998 and 2000 by the National Parks and Wildlife Service (NPWS), the Irish Raptor Study Group (IRSG) and Birdwatch Ireland (BWI) which estimated the breeding population as between 102 and 129 pairs (Norriss *et al.*, 2002).

The second national survey in 2005 reported an increase in the breeding population with between 132 and 153 pairs in 66 10km squares (Barton *et al.*, 2006). Following the 2005 survey (and 2004 Northern Ireland survey, Sim *et al.*, 2007) the conservation status of the hen harrier in Ireland was changed from red-listed to amber-listed due to the apparent increase in the population (Lynas *et al.*, 2007) and the species remains amber-listed on the *Birds of Conservation Concern in Ireland* (Colhoun & Cummins, 2013) whilst it is red-listed in the UK (Eaton *et al.*, 2015).

The third national survey in 2010 estimated 128 to 172 breeding pairs which were recorded within 69 10km squares (Ruddock *et al.*, 2012). The national population at that time therefore appeared to be relatively stable since the previous national survey although the accuracy of the estimates of change were complicated due to more than double the survey effort during 2010 compared to the 2005 survey. Consequently in some areas the recorded numbers of hen harriers had increased, but this was largely a reflection of additional field effort. Regardless, there were severe regional declines noted particularly in the Slieve Aughties and in the Stack's, Glanarudderies, Knockanefune, Mullaghareirks, North of Abbeyfeale complex. The numbers of confirmed breeding pairs (see Barton *et al.*, 2006 for definitions) in Ireland declined marginally between 2005 and 2010 (3.3%) but apparently increased (25.5%) from the 1998 – 2000 surveys although survey effort was also increased considerably.

Due to the variation in observer effort between surveys, a more accurate means of deriving population change is to control for recorded effort by comparing a subset of 10km squares which were covered across surveys. An analysis of the number of confirmed and possible breeding pairs within a subset of 113 10km squares which were surveyed in both 2005 and 2010 recorded a decrease of 6.4% over this period (2005 – 2010).

Similarly, a direct comparison of the population estimates between the first (1998 – 2000) and third (2010) national hen harrier surveys indicates a maximum population increase of 25 pairs (33%). However the recorded effort for the 2010 survey was substantially greater compared with the first national survey. In order to control for survey effort a sub-sample of 84 10km survey squares which were covered during both surveys was interrogated to derive a short-term population trend. In 1998 – 2000 a total of 110 – 152 pairs were recorded within the 84 survey squares. When this is compared with the 98 – 131 pairs from the 2010 survey a decline of 11 (14%) is calculated.

In 2007, as a requirement under the EU Birds Directive, Ireland designated six sites as SPAs based on their national importance for breeding hen harriers (see www.npws.ie/protected-sites); (i) the Slieve Bloom Mountains SPA (Site code: 4160); (ii) the Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPA (Site code: 4161); (iii) the Mullaghanish to Musheramore Mountains SPA (Site code: 4162); (iv) the Slievefelim to Silvermines Mountains SPA (Site code: 4165); (v) Slieve Beagh SPA (Site code: 4167); and (vi) the Slieve Aughty Mountains SPA (Site code: 4168). Between 2005 and 2010, the numbers of hen harriers within these SPAs varied regionally, with three SPAs declining and three increasing over this period, although overall numbers declined by 18.1% since the 2005 survey (Ruddock *et al*., 2012).

Ruddock *et al*., (2012) suggested that limited breeding resources may be impacting hen harrier populations in Ireland. The proximate or distal causes of the regional declines include potentially contributing factors such as over-winter survival rates (O'Donoghue, 2011), habitat suitability/change particularly of afforested areas (Wilson *et al*., 2012), predation, persecution, reduction in food supply, development (e.g. windfarms, O'Donoghue *et al*., 2011) and various disturbance factors e.g. peat-cutting, burning etc (Ruddock *et al*., 2012).

It was therefore opportune to collect and compile further information on pressures at regional and national levels such as those identified by Ruddock *et al*., (2012) e.g. turf-cutting, forestry operations, windfarms, recreational activities and also to inform future Article 12 reporting and the HHTRP process. This may also provide information to help establish the likely causes of changes in hen harrier distribution and the factors which may influence occurrence and distribution since the last surveys.

As well as determining national population size, distribution and trends, monitoring also provides an opportunity to investigate aspects of population ecology such as breeding behaviour, habitat usage and

more specifically productivity since these ecological aspects may vary in response to changes in habitat quality/quantity, prey availability/density, weather and nesting failure due to anthropogenic disturbances and/or predation (Etheridge *et al*., 1997; Green & Etheridge, 1999; Redpath & Thirgood, 1999; Salamolard *et al*., 2000; Amar & Burthe, 2001; Madders, 2003; Amar *et al*., 2003; Amar *et al*., 2004; ; Amar & Redpath, 2005; Amar *et al*., 2008; Whitfield *et al*., 2008; Wilson *et al*., 2009; Amar *et al*., 2011; Irwin *et al*., 2011; McMillan, 2014). Long-term monitoring on a national scale may also provide data for analyses of population changes at pan-European and continental scales in response to global environmental factors such as climate change (Devictor *et al*., 2008; Juilliard *et al*., 2004).

As per the Birds Directive; monitoring, research and the establishment and maintenance of protected areas are important components for the conservation of this species. In addition, survey and monitoring data collected during national surveys are necessary for use by the government and other agencies to help inform management and conservation decisions. Several declines were recorded between 2005 and 2010 and it is important that a re-survey is undertaken to establish the status of the species in Ireland.

The Golden Eagle Trust, Irish Raptor Study Group and BirdWatch Ireland formed a partnership to co-ordinate the 2015 Irish Hen Harrier Survey on behalf of the National Parks & Wildlife Service of the Department of Arts, Heritage & the Gaeltacht. This report has four key objectives:

1) Obtain a reliable estimate of the size of the hen harrier breeding population in the Republic of Ireland in 2015;

2) Obtain a reliable estimate of the distribution of the hen harrier breeding population in the Republic of Ireland in 2015;

3) Estimate the change in population size and distribution since the last surveys in 1998 – 2000; 2005 and 2010; and

4) Compare the distribution and size of the hen harrier populations within the six Special Protection Areas (SPAs) since the surveys in 2005 and 2010.

2.0 Methods

2.1 Objectives

In order to establish the required population estimates at various scales, the primary objective of the hen harrier field survey is to establish whether potentially suitable habitat is occupied by hen harriers in the breeding season. Secondary objectives are to establish whether a breeding attempt was initiated and to establish the breeding outcome (i.e. success or failure of a nest and if successful, establish the number of fledged young).

It is important that all areas of potentially suitable habitat are surveyed and not only the areas within the historical range. Provided suitable habitat exists hen harriers will utilise habitat resources which often vary temporally and spatially particularly in maturing forest plantations. Therefore, it is necessary to define the survey area as currently suitable breeding habitat as well as targeting historical territories or known nest sites (see Hardey *et al*., 2013).

2.2 Survey design and implementation

Potentially suitable breeding regions for hen harriers were identified according to mountain ranges/upland areas, typically within the elevation range of peaks between 200m and 600m above sea level (ASL), although hen harriers can utilise a range of elevations (36 – 385m; O'Donoghue, 2010). These areas were divided into individual survey units using the 10km x 10km national Irish grid squares and further defined within a series of mountain or upland ranges (see also Norriss *et al*., 2002; Barton *et al*., 2006; Ruddock *et al*., 2012). The primary areas allocated for survey within the breeding range of the hen harrier were defined as those 10km national grid squares within which hen harriers were observed during the 1998 – 2000 (Norriss *et al*., 2002), 2005 (Barton *et al*., 2006) or 2010 (Ruddock *et al*., 2012) national surveys, or where recent occupation by hen harriers during the breeding season was known from other reliable sources.

Such sources included supplemental records from 2006 to 2014 provided by the Irish Raptor Study Group annual monitoring scheme, the NPWS' species database, BirdWatch Ireland raptor database, ecological consultant data (primarily from windfarm studies) and a review of hen harrier records from the Breeding Atlas data (2007 to 2011 inclusive; Balmer *et al*., 2013). In addition, squares within the historical range of the species and/or known to contain suitable nesting habitat were also included.

This yielded a total of 308 10km squares that were known to previously support breeding hen harriers and/or suitable breeding habitat in the Republic of Ireland. The squares were prioritised for survey coverage and allocated amongst fieldworkers as follows (i) 104 'green' squares where breeding had

been confirmed (see Barton *et al*., 2006; Ruddock *et al*., 2012; Balmer *et al*., 2013) in the period 1998 – 2014; (ii) 28 'yellow' squares where breeding had been recorded as possible (see Barton *et al*., 2006; Ruddock *et al*., 2012) in the period 1998 - 2014 (iii) 116 'orange' squares in which hen harriers had been sighted in the period 1998 – 2014 and/or where suitable habitat was recorded and (iv) 60 squares which had no historical hen harrier sightings and/or known suitable breeding habitat.

Geo-referenced OSI 1:50,000 maps and aerial photographs for each of the 10km survey squares survey were digitised using ArcView 10.1 and provided to fieldworkers. The maps included the OSI 1:50,000 background showing habitat, contours and a labelled 1km grid layer to allow calculation of spatial references for sightings, nest locations etc. derived from the field maps (see Appendix 1). The aerial photographs (taken in 2013) showed in further detail the extent of forest boundaries and allowed discrimination between improved grassland and unimproved grassland or moorland and afforested habitats (see Appendix 2).

The names and contact details of potential fieldworkers were derived from the contact databases of regional hen harrier researchers, the NPWS staff, the Irish Hen Harrier Winter Survey volunteers, Golden Eagle Trust staff and members, IRSG members and volunteers, BirdWatch Ireland staff, members, and volunteers, ecological consultants and other independent raptor fieldworkers. Fieldworkers were invited to participate in the survey and also to attend training workshops via email and telephone contact. Seven workshops were undertaken to standardise fieldwork methods, distribute maps and aerial photographs and allocate survey squares.

2.3 Defining survey areas

The survey areas were further defined based on (i) core areas i.e. using historical information (e.g. Norriss *et al*., 2002; Barton *et al*., 2006, Ruddock *et al*., 2012; Balmer *et al*., 2013) of preferred/known nesting areas and including, but not limited to traditionally monitored areas); (ii) non-core areas including, but not limited to suitable habitat (primarily moorland and afforested areas) elsewhere in Ireland (notably in the east and west of the island); and (iii) random areas selected to assess biases in core and non-core areas. The unit of investigation for each of these areas utilised the Irish National Grid at the 10km square resolution.

All existing and historical hen harrier data was collated including that derived from all previous national survey databases (Norriss *et al*., 2002; Barton *et al*., 2006; Ruddock *et al*. 2012), IRSG databases and Bird Atlas 2007 – 2011 (Balmer *et al*., 2013) and aggregated into ArcGIS. This identified a total of 308 10km squares that were previously surveyed and/or known to have historically contained harriers and/or contain suitable hen harrier breeding habitat(s). This also included 12 randomly selected squares containing suitable habitat within geographically unsurveyed areas.

All squares were digitised in ArcGIS (see Appendix 1 & 2; Figure 1) and assigned into categories to include:

(i) survey zone (for regional co-ordination purposes; Zone 1; Zone 2 and Zone 3);

(ii) squares which are within the SPA designations;

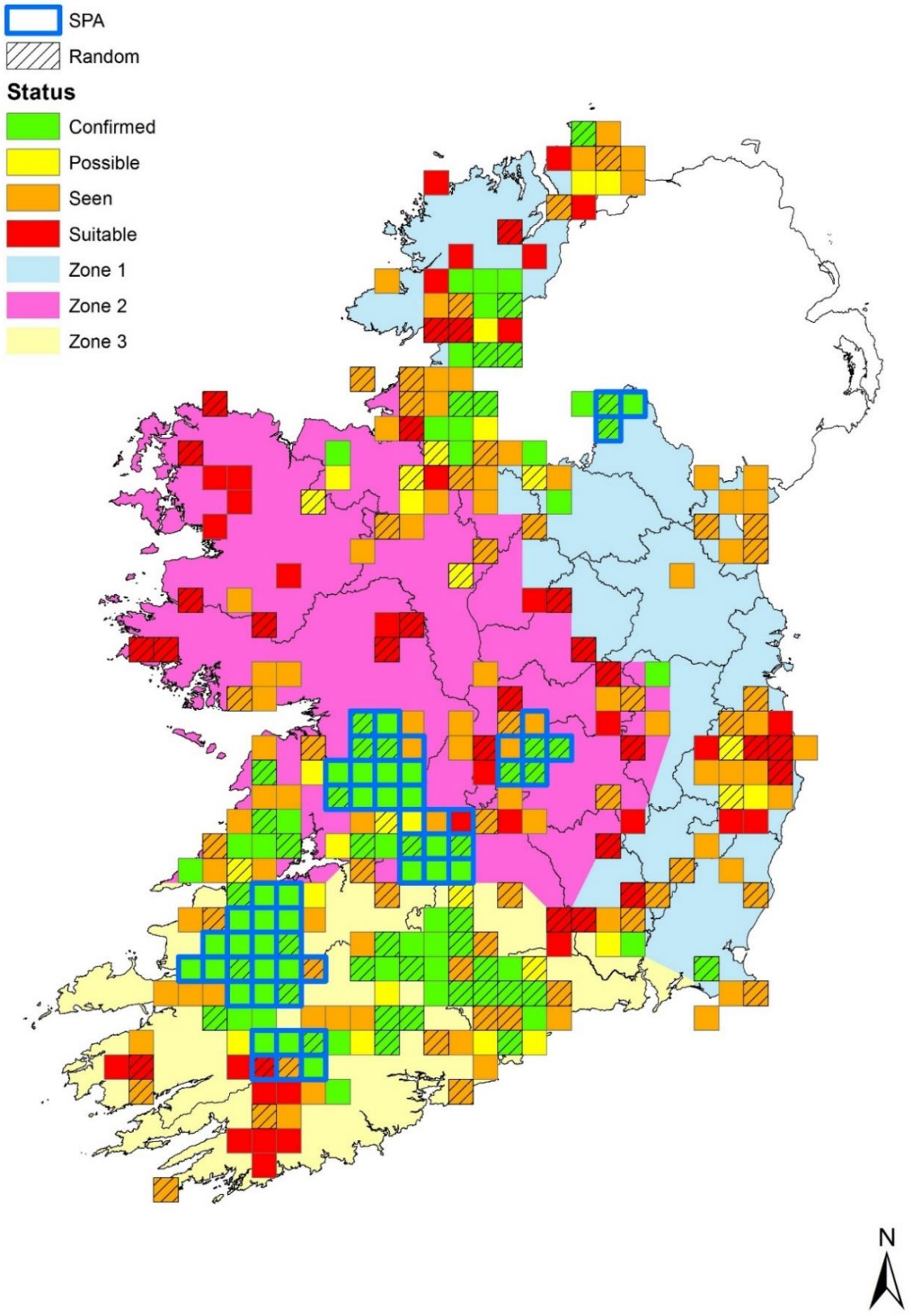
(iii) the previous maximum known breeding status of hen harriers (confirmed, possible, seen, not seen);

(iv) random squares (n = 125) selected from within the hen harrier breeding range / suitable habitat for specific survey to assess biases in square based census approach previously adopted (see Ruddock *et al*., 2012);

(v) an additional layer of prioritisation was implemented to ensure the subset of 113 squares surveyed in both 2005 and 2010 (see Ruddock *et al*., 2012) were repeated in the 2015 national survey.

Individual 10km square maps were also produced in ArcGIS in PDF format to include a 1:50,000 OSI base layer and orthophotography for identification of suitable/unsuitable habitats (see Appendix 2 & 3). Additionally SPA base layer maps incorporating the NPWS habitat map layer (Moran & Wilson-Parr, 2015) were also produced (Appendix 3) in order to support field surveyor effort.

Figure 1. Map showing the selected 10km squares for survey during 2015 including the historical maximum breeding status, designated zones and randomly selected squares.



2.4 Hen harrier field surveys

Prior to commencing the fieldwork, the surveyors used the maps and aerial photographs of each 10km grid square to exclude unsuitable habitat; identify areas of potentially suitable hen harrier breeding habitat; and to locate suitable vantage points for the timed observations. The suitability of these areas was confirmed during the first visit by driving through the square to "ground-truth" likely breeding habitats.

Direct field surveys utilised particular vantage points, in order to minimise topographical constraints and to reduce disturbance (located ± 300 - 2000 m from nests; see Ruddock & Whitfield, 2007; Hardey *et al.*, 2013). Vantage points were intended to observe historical nest locations and all areas of suitable breeding habitat at least once per calendar month during the breeding period. This entailed 4-6 visits/per territory/suitable habitat areas; dependent on time taken to locate nest areas and establish breeding success within the survey area.

Breeding habitat was defined as either suitable or unsuitable (see Ruddock *et al.*, 2012; Hardey *et al.*, 2013). Suitable breeding habitats are defined as:

- heather dominated and/or grass moorland,
- other open habitats with extensive scrub or bramble cover and
- developing pre-thicket forest (first and second/subsequent rotation crops).

Unsuitable habitat was identified and excluded from maps and survey effort. Unsuitable areas were defined as:

- ground above 600m;
- built-up/urban areas or within 100m of occupied farm buildings and dwellings;
- improved pasture and arable farmland;
- the interior of unbroken, closed-canopy forest blocks;
- enclosed or unenclosed areas of heavily grazed sheep pasture (sheep-walk);
- extensive areas of bracken;
- degraded or overgrazed upland areas without any heather or vegetative cover; and
- areas within close proximity to sea-cliffs, inland crags, rocky outcrops, boulder fields and scree slopes

Particular attention was paid to heather moorland which contained stands of deep (usually >0.4m tall; see Redpath *et al.,* 1998; Ruddock *et al.,* 2008), well-drained heather with greater than 50% cover and areas with good all-round visibility such as slopes and river valleys and deep heather areas within forest clearings, forest rides and heather at the edges of forest plantations. The latter is usually found

where livestock are excluded by fencing associated with afforestation and/or unplanted areas within the forest ownership boundary (Ruddock *et al.,* 2008).

Grass-dominated and degraded moorland were also surveyed where these contained patches of deep heather or other shrub cover. Other shrub-dominated areas such as river valleys, abandoned fields and scrubby bogs were included in the survey. Pre-thicket coniferous forests were surveyed and particular attention was paid to areas where forest compartments were characterised by prolific shrub layers.

Mature coniferous forests were surveyed where hen harriers observations were regularly associated with post-thicket stage plantations since tree-nesting has been recorded in Northern Ireland (Scott *et al.,* 1991; Ruddock *et al.,* 2008) and harriers will often nest in rides or lacunae within mature plantations. In addition, areas of scrub (e.g. willow and bramble), often on the edges of moorland or bog, were surveyed for occupancy by hen harriers.

Following the guidance of previous surveys (Barton *et al*., 2006; Ruddock *et al*., 2012) and standardised methods for raptor surveys (Hardey *et al*., 2013) suitable habitat within all survey squares were preferably visited on four occasions between late March and the end of July, with a minimum of three visits required. Firstly, two visits to establish territorial occupancy were required with the first visit between late March and mid-April and the second between mid-April and mid-May. These two visits were the most important as this helps identify where the hen harrier territories may occur. A third survey visit was recommended during the late May to late June period to establish evidence of breeding, with particular emphasis on locating active nests, where these are not already located. A fourth visit was required between late June and the end of July to confirm nest activity and whether recently fledged birds were observed to establish breeding outcomes.

Table 1. Summary of hen harrier breeding season (Hardey *et al*., 2013).

Breeding activity (No. of days)	**Range**	**Peak period**
Site occupation & display	Late February to late May	Early April to early May
Nest building	April to late May	-
Egg laying (5-12 days)	Mid-April to late June	Late April to mid-May
Incubation (29-31 days)	Mid-April to late July	Late April to mid-June
Hatching	Mid-May to late July	Late May to mid-June
Young in nest (28-39 days)	Mid-May to late August	Late May to mid-July
Fledging	Mid-June to late August	Late June to mid-July
Juvenile dispersal	August to September	-

These survey visits reflect the seasonality of the hen harrier breeding activities (see Table 2) and includes the periods of territorial display/mate advertisement, incubation, nestling and fledgling periods (Hardey *et al.,* 2009). The additional visit between late May and late June is to increase the

likelihood of detecting a nest location (Hardey *et al.,* 2009) and to acquire ancillary information from the hen harrier sightings, such as habitat usage derived from additional visits.

Table 2. Behaviour codes and descriptions utilised during the survey.

Behaviour (Code)	Description of behaviour
Display (D)	Including "sky-dancing" or aerial display involving rapid stooping and climbing and occasionally mutual or individual high circling may be observed
Food pass (FP)	Male passing food to the female or adult to juvenile, usually in mid-air
Hunting (H)	Low level "quartering" flights <5m above ground level
Flying (F)	Flying or commuting where no other behaviours are recorded
Alarm (A)	Adults calling or appearing agitated, usually occurs close to the nest during territorial defence
With Prey (WP)	Carrying prey in its talons
Soaring (S)	Circling very high (above tree-tops) on thermals
Circling (C)	Circling below tree-top height
Perched (P)	Perched on a tree or fence post
on Ground (G)	Perched on the ground
Mobbing (M)	Territorial behaviour and chasing or attacking other harriers or other bird species. May occasionally be observed to attack mammal predators
Other (O)	Other behaviour(s) where not adequately described by any other category above

Hen harriers can breed in close proximity to each other (Watson, 1977; Balfour & Cadbury, 1979; Simmons, 2000; Garcia & Arroyo, 2002; 2005 O'Donoghue, 2010) and often have overlapping foraging ranges (Arroyo *et al.,* 2004). Moreover, individuals can differ in their expression of territorial behaviour (Garcia & Arroyo, 2002). During each survey visit, surveyors observed potential breeding habitat for 2.5 to 3 hours from strategic vantage points that offered unrestricted views and were located, as far as practicable, to reduce possible disturbance. The minimum distance from known nest sites recommended for vantage points was 500m to 700m (Ruddock & Whitfield, 2007; Whitfield *et al.,* 2008). The same vantage points were used for each subsequent visit although, where necessary, if hen harrier activity was identified and required additional and/or relocated vantage point locations these were also surveyed.

For the purposes of this report a territory is defined as any area of suitable habitat surveyed and/or occupied by apparently breeding hen harriers. Each hen harrier record was assigned to a putative territory identified by the nearest townland name or name appearing on the 1:50,000 map closest to the area of suitable habitat surveyed. The date, place-name (derived directly from the 1:50,000 map) of the area surveyed, duration of survey effort and six figure grid references of vantage points were recorded. Where hen harriers were detected, fieldworkers provided information on the location of the sighting

(six figure grid reference), number, age and sex of all hen harriers encountered. A brief description of behaviour (particularly where indicative of breeding activity, see Table 2) was also recorded along with a description of the dominant habitat type(s) within 100m of the sighting (see Table 3).

Table 3. Habitat codes and descriptions utilised during the survey.

Habitat (Code)	Description of habitat
First rotation (or new) forest (1F)	First-rotation forest plantations before canopy closure. Characterised by prolific herb layer with varying shrub layer development. Trees generally >1m tall with large open spaces between lines of planting.
Second rotation forest (2F)	Second-rotation forest plantations before canopy closure. Characterised by varying shrub layer development and brash and tree root-plates from the previous crop and large open spaces between lines of planting. Newly established second-rotation trees are not always obvious. Third rotation crops are likely in future years but none were recorded in this survey.
Thicket (pole) or mature stage forest (T)	Closed-canopy forest plantations including both 1F & 2F 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.
Clearfell (CF)	Harvested plantation not yet restocked with trees. Characterised by limited development of herb and shrub layer, and brash and tree root-plates evident from the previous crop.
Heather moorland/bog (H)	Unenclosed heather-dominated moorland characterised by species such as heather, bilberry and purple-moor grass plus blanket bog characterised by ling and bell heather, bog cotton, deer grass and moss. Typically grazed by red 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 rush (*Juncus* spp.) and bracken (*Pteridium* spp) 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 (*Juncus* spp).
Improved grassland (IG)	Enclosed pastures that have been drained, fertilised or re-seeded characterised by lush green grass vegetation and containing higher densities of sheep or cattle. Also includes hay meadows.
Scrub (S)	Areas outside or away from plantation forests consisting of willow, bramble, furze etc which have not been tended by humans. Includes bushy vegetation such as willow (*Salix* spp), gorse (*Ulex* spp), bramble (*Rubus* spp), alder (*Alnus* spp), birch (*Betula* spp) and bracken (*Pteridium* spp).
Linear feature associated with rough grassland (LR)	Linear feature (e.g. hedgerows, ditches and drainage channels) that are contained, or in close proximity to, rough grassland
Linear feature associated with improved grassland (LI)	Linear feature (e.g. hedgerows, ditches and drainage channels) that are contained, or in close proximity to, improved grassland
Other (O)	Description of habitat where it does not fall into one of the categories outlined above.

Where possible, the age and sex of harriers was also recorded, size and plumage colouration varying considerably between adult male and female hen harriers (Watson, 1977; Newton, 1979; Hardey *et al.*, 2009). Guidance during workshops and photographs (see also O'Donoghue, 2010b) were provided to

fieldworkers to distinguish the more subtle differences in plumage and behaviour between harriers of different sex and age combinations.

Fieldworkers followed or mapped the routes of foraging hen harriers observed during vantage points to opportunistically collect information on habitat use as well as to establish connectivity with adjacent or nearby breeding habitat. This was to identify other breeding areas or whether sightings originated from known breeding areas. Where possible, observations were made simultaneously by two or more surveyors in neighbouring territories to identify suspected polygynous breeding attempts (see Amar *et al.* 2003) and/or differentiate between individual hen harriers.

Nests were located by observing females after food passes by males, or from repeated observations of harriers dropping into suitable nest habitat. Where nests were located, fieldworkers provided six grid references and details of nest habitat type marked on recording forms and maps. Finally, for each 10km square, surveyors were requested to annotate maps showing areas of suitable habitat and identify nest locations where applicable.

The survey organisers liaised with fieldworkers throughout the season via email and phone updates to improve survey coverage where required and to receive feedback on the survey progress. Fieldworkers were also encouraged to communicate directly with each other and regional co-ordinators to minimise the duplication of effort (see Ruddock *et al.,* 2008).

2.5 Data recording and data entry

Method statements, recording forms, press releases and details of the project website (www.irishhenharriersurvey.com) were all notified and/or sent to surveyors. In order to understand where sightings or breeding activity occurred observers were encouraged to submit records throughout the survey period and post-survey. Observers were requested to submit all records by the 31st August 2015 to allow time to input and analyse the data.

Printed maps and forms were provided for use during field surveys and these forms and maps were submitted in hard-copy and returned by post to one of the regional co-ordinators in Dublin, Limerick or Galway. Alternatively, data was also entered directly by observers into the survey excel spreadsheets and emailed to irishhenharriersurvey@hotmail.com or any of the project managers directly. Observers were then also requested to scan and email survey maps or post the maps to the co-ordinators. Hen harrier data was also entered online (www.irishhenharriersurvey.com) either by the public sightings page (www.irishhenharriersurvey.com/report-a-hen-harrier-sighting/) or via the detailed data entry portal (www.irishhenharriersurvey.com/hen-harrier-survey-data-submission/) which were utilised to

record all information collected from vantage point locations and also square summary and territory data.

2.6 National and regional population estimates, population change and breeding density

Territories, i.e. areas of suitable habitat, were all classified according to observed breeding activity as 'confirmed', 'possible', 'seen' or 'not seen'. To ensure comparability these categories were based on previous survey criteria (see Barton *et al.,* 2006; Table 4). A territory was considered to be occupied by a pair ('pair-occupied') if two birds were seen simultaneously within the range. A territory was considered to be 'single occupied' if only one bird had been observed and this individual could be excluded from belonging to a neighbouring territory by independent observations (or by the absence of a known neighbouring territory).

Where a territory was classified as confirmed or possible despite only a single bird having been recorded during observations it was deemed a confirmed breeding pair (e.g. where only a female was observed carrying food to an active nest and no male was seen; see Table 4) or a possible breeding pair (e.g. male bird seen displaying on multiple occasions and could be discriminated from separate territories; see Table 4). The survey co-ordinators analysed all raw data provided, with a view to ensuring independent territories were correctly identified and/or where necessary clarified with regional co-ordinators and directly with surveyors the status of the territory. The key criteria is that territorial and/or breeding behaviours indicative of breeding and the repeated presence of birds was used to classify status. This minimises the risk of over-estimation of activity based on sightings of foraging or birds only casually present in an area. Throughout the report these territorial classifications are termed confirmed or possible breeding pairs.

Table 4. Classification of breeding status

Breeding status	Behaviours, evidence and/or activities observed
Confirmed breeding	Food pass observed
	Adult carrying prey
	Recently fledged young
	Agitated behaviour or calls given by adults
	Direct evidence of a nest (eggs or chicks seen, chicks heard, used nest or eggshells found)
	Courtship or display behaviour involving both a male & female noted on two visits separated by at least a week
	A pair seen visiting a probable nest site on two visits separated by at least a week
	Nest building or carrying nest material
Possible breeding	Courtship or display behaviour involving both a male & female noted on only 1 visit, or only
	Only one bird is ever seen (e.g. displaying male seen twice but no female seen)
	A pair seen visiting a probable nest site on only one visit
	Pair or female seen in possible nesting habitat between mid-May & end of June
Seen	Single male, female or pair (outside mid-May & June) observed with no evidence of breeding behaviour
Not seen	Area of suitable breeding habitat with no observations of hen harriers

National and regional population estimates for breeding hen harriers were derived by adding the total number of confirmed territories to the number of possible territories to obtain minimum and maximum population estimates i.e. the range of confirmed to confirmed + possible territories. Where estimates were available from the 1998 – 2000 (Norriss *et al.*, 2002); 2005 (Barton *et al.*, 2006) and 2010 (Ruddock *et al.*, 2012) hen harrier surveys the national and regional population changes were examined by calculating the percentage change in the estimates across the four surveys. Additional estimates of national population change was derived by comparing the total number of pairs found in the subset of squares surveyed during both the 2005 (Barton *et al.*, 2006); 2010 (Ruddock *et al.*, 2012) and 2015 (this study) national surveys and also in the NPWS 1998 – 2005 database (Norriss *et al.*, 2002; NPWS, unpublished data). In this study three separate subset analyses were undertaken; (i) the comparison of squares surveyed in both 2015 and 2010; (ii) the comparison of the subset of squares survey in 2015; 2010 and 2005; and (iii) the subset surveyed in all four national survey periods 2015; 2010; 2005 and 1998 – 2000. The use of such subset analyses reduced the risks of biases created by increasing survey effort and survey area over time and allows direct comparison of changes between years. However, since survey effort and survey area has increased over time there was a declining number of squares covered

in each of the subset analyses (i: n = 139; ii: n = 113; and iii: 78) but regardless this method allows more comparable estimates of change, i.e. increase or decline, over time.

Whilst breeding pairs in the national surveys are defined based on categorical (behavioural) observations, in order to compare estimates between survey years the mid-point value of each of the survey ranges (confirmed pairs to confirmed + possible pairs) was also used to compare estimate of increase or decrease between surveys. Mid-point values can be used in population estimates (Anthony *et al*., 1999) to compare 'calibrated' figures particularly where effort varies between surveys (Cao *et al*., 2008). Therefore no weighting in this mid-point estimate was given to the discrete categorical classification of breeding pairs but rather it provides a further comparison of population estimates between surveys. In order to identify high density areas, the number of pairs within each square was reviewed and classified as a 'high density' square where a minimum of three confirmed or possible territories were recorded following the methods of Barton *et al.,* (2006).

2.7 Population estimates, population changes and habitat composition within SPAs

Estimates of population change were calculated, where possible, for the six SPAs designated for breeding hen harriers in Ireland. The areas which were surveyed during both the 2005 (pre-designation); 2010 and 2015 (post-designation) surveys were identified and the numbers of breeding pairs found were compared between the three surveys. This was achieved, firstly, by comparing the 10km square summaries for each of these areas between the three surveys. Secondly, in order to increase the accuracy of the estimates, a point feature database was created in ArcView 9.3 of all confirmed and possible territories recorded in the survey and calculating the number of territories within the polygon (updated September 2010) of each SPA boundary.

Territory locations, for this analysis were plotted at a six figure grid reference resolution if the nest was located and a four figure grid reference resolution if no nest was located. The territory is plotted centrally by convention i.e. centrally in the 1km square of breeding activity. Due to the spatial error associated with plotting such grid references, where territories were in close proximity to the polygon boundary, the distance from the point to the boundary was calculated to assess inclusion in, or exclusion from, the SPA. This was to establish if the territory was within 100m of the boundary for six figure grid references and within 1000m of the boundary for a four figure grid reference. The number of breeding pairs in 2010 in each SPA was also compared to the population counts used to designate the SPAs originally (see Barton *et al*., 2006).

A further spatial analysis was undertaken to establish the number of territorial pairs which were located within 500m and 2km of each SPA boundary which may be dependent on the SPAs for breeding season requirements e.g. foraging. This was undertaken by using the proximity tool in ArcGIS to create a buffer to allow identification of those adjacent territories within 500m and 2km.

2.8 Breeding outcomes and habitats utilised

The breeding activity at nest locations was established through behavioural observations from vantage points at a distance from nest sites (Hardey *et al.,* 2006; 2009; 2013). Nest visits were not required as part of the survey effort. However, a small sample of nests were visited under licence to undertake brood counts, wing-tagging, install nest cameras and post-breeding to investigate nest contents.

Behavioural observations were used to infer the status of nesting attempts as to whether incubation had started. That is, before incubation begins, females typically do not fly from the nest to receive a food-pass from the male, and do not return to the nest directly after feeding. After incubation has begun, however, females tend to fly directly from their nests to receive food-passes, and fly back to the nest after feeding, often carrying nest material. Behavioural evidence was also used to infer hatching, after which females (and, later on, males) deliver prey directly to the nest. The female usually removes prey remains from the nest following feeding until the young are well-feathered and approaching fledging. Therefore, post-season nest visits can also be useful in establishing breeding outcome (Hardey *et al.,* 2009). Surveyors who held appropriate licences visited nest sites to monitor breeding performance by recording clutch size, brood size and the number of fledged young. Nest visits prior to incubation were not undertaken due to the potential sensitivity of breeding harriers to disturbance at this time (Hardey *et al.* 2006; 2009; O'Donoghue, 2010; Hardey *et al*., 2013).

Territories were classified as 'successful' where at least one young fledged from a confirmed breeding territory (Green & Etheridge, 1999; Barton *et al.,* 2006). Breeding failure was determined either (i) by licenced nest visits; (ii) when no activity was recorded on third and fourth visits to the area of a previously active nest; (iii) if no fledged chicks were observed during at least two visits between early July and the end of July; or (iv) if late-season nest visits confirmed that the breeding attempt had failed. Territories with uncertain breeding outcome, when no fourth visits (during late June to the end July) were conducted or when no evidence was provided by the fieldworker that a breeding attempt was initiated were classified as 'outcome unknown'.

Where nest locations were identified, habitat was broadly classified within 10m of the nest as: heather/bog; first rotation forest; second rotation forest; failed forest; scrub (where isolated from plantation forest); mature forest (i.e. tree nests), or unknown, where the precise nest location was not explicitly identified.

2.9 Pressures

Further to the analysis of ad-hoc recordings of putative disturbance and/or activities recorded in 2010 (Ruddock *et al*., 2012) a more strategic approach to the understanding of pressures recorded within the vicinity of hen harrier territories and/or areas of suitable breeding habitat was undertaken in 2015.

For this purpose, the pressures were defined as any activity, management, or action which the observer considered may influence hen harriers and/or the suitability of the habitat and area for breeding. Such pressures could be considered during recording to be either positive or negative, but no analysis of this was undertaken in this report.

Observers were requested to record the activities/threats or pressures observed, if any, within 500m and within 2km of the survey area (Table 5) to facilitate a strategic assessment of regional and national information on these metrics. The information and options included in the pressure codes was derived from a review of the EU Bird Directive reporting matrix for standardised recording of these factors and will therefore increase the utility of this information for future reporting under Article 12 of the Birds Directive.

For the purposes of analysis, in order to understand the frequency of pressures there were two pressure indices created, (i) Pressure Index 1 which was a total count of all pressures recorded by observers within 500m and 2km and (ii) a standardised Pressure Index 2, which was to reduce any bias created by survey effort between squares and/or nest site, which was the total number of pressures divided by the total number of visits to square to obtain a standardised metric. Both indices are used as the maximum number of records provides valuable information about the perceived magnitude of pressures and the standardised index reduces any biases that may occur.

Table 5. Pressures codes and descriptions for use on recording forms.

Code	Description of pressure
A1	modification of cultivation practices
A2	agricultural intensification
A3	mowing / cutting of grassland
A4	abandonment / lack of mowing
A5	intensive grazing
A6	non intensive grazing
A7	abandonment of pastoral systems, lack of grazing
A8	fertilisation (agricultural)
A9	removal of hedges and copses or scrub
B1	forest planting on open ground (increase in forest area, planting e.g. on grassland, heathland)
B2	forest and plantation management & use
B3	forest replanting (i.e. replanting on forest ground after clear-cutting)
B4	forest clearance (clear-cutting, removal of all trees)
B5	thinning of tree layer
B6	fertilisation (forestry)
B7	other forest activities (e.g. erosion due to forest clearing, fragmentation)
C1	hand cutting of peat
C2	mechanical removal of peat
C3	wind energy production
D1	paths, tracks, cycling tracks (includes non-paved forest roads)
D2	roads, motorways (all paved/ tarred roads)
D3	utility and service lines (e.g. power-lines, pipelines)
D4	aircrafts or flightpaths
D5	improved access to site
E1	urbanisation, residential and commercial development
E2	dispersed habitation (i.e. little or no human disturbance)
F1	nest destruction
F2	illegal killing (e.g. shooting, trapping, poisoning)
G1	human intrusions and disturbances
G2	outdoor sports and leisure activities, recreational activities
G3	walking, horse-riding and non-motorised vehicles
G4	motorised vehicles
G5	off-road motorised driving
G6	other outdoor sports and leisure activities
G7	military manoeuvres
H1	pollution (e.g. water pollution, fly-tipping)
J1	natural fires
J2	controlled burning (e.g. strip burning for grouse management)

J3	uncontrolled burning (e.g. widespread unmanaged or malicious burning)
J4	modification of water levels or waterbodies
J5	reduction or loss of specific habitat features (e.g. removal of hedgerows, deep heather, scrub, walls, drains)
J6	reduction of prey availability
J7	anthropogenic reduction of habitat connectivity (i.e. fragmentation such as by removal of large areas of habitat or creation of barriers between habitats)
K1	interspecific faunal relations - predation (by other birds e.g. crows)
K2	interspecific faunal relations - predation (by mammals e.g. foxes)
X	no pressures recorded
O	other pressures not listed above

2.10 Other research

During fieldwork, surveyors specifically recorded additional data including any suspected nest disturbance and persecution of hen harriers, weather conditions, details of wing-tagged hen harriers encountered and sightings of other raptor species (including six figure grid references) or other upland or priority species (e.g. red grouse, golden plover, curlew, snipe). In addition, fieldworkers who held nest visit licences searched nest areas for moulted feathers and prey remains or visited nests after the breeding season. Protocols for the collection, storage and labelling of samples were provided to fieldworkers (see Ruddock *et al*., 2012).

3.0 Results

3.1 Survey implementation, coverage and data submission

A database of 436 potential surveyors was created which included surveyors who previously took part in National Hen Harrier Surveys, the Bird Atlas project, raptor fieldworkers, BWI volunteers and local branches, IRSG volunteers, GET volunteers and NPWS staff. Potential surveyors were requested via email contact in early March to participate in the survey. The survey registration was available online at https://www.surveymonkey.com/s/JVF95TJ and information was also circulated to all registered users of the social media platforms of all three co-ordinating organisations.

There were 171 people registered online to take part in the survey of which 129 indicated they would attend one of the training workshops. A small number subsequently indicated they would not be able to participate or felt they did not have adequate experience or time to conduct surveys. At completion there were a total of 259 surveyors who had submitted records and/or participated in monitoring of survey squares.

Seven training workshops were delivered in Charleville (x2), Athlone, Gort, Donegal, Cavan and Wicklow. These workshops provided a detailed presentation to the fieldworkers on hen harrier ecology, the survey methods and on the allocation of regional survey squares.

There were numerous "new" surveyors recruited during 2015, which is hugely positive, however this necessitated some additional field training workshops and team field work. These were conducted in County Louth, County Cavan, County Leitrim, County Donegal, the Slieve Aughties, Slieve Beagh, the Ballyhouras and Nagles and these fieldtrips also facilitated team coverage of several survey squares throughout the survey period.

There was on-going submission of data throughout the survey period via the online survey portal during the season but the majority of data were received post-breeding season between 15th August 2015 and 22nd October 2015. There were 254 squares initially allocated to volunteers, with additional project team effort required to fill areas where volunteer availability was low. The squares which historically had confirmed or possible breeding ('green' or 'yellow') squares, are part of the SPA network and/or randomly selected squares (see Figure 1) were prioritised for allocation and coverage in the first instance.

Initially there were 254 of the 308 selected survey squares (Figure 1) allocated for coverage. This included the initial allocation of all but one (99%) 'green' squares and the majority of 'yellow' (78.6%) and 'orange' squares (78.4%) and 63.3% of 'red' squares which were considered to contain suitable habitat.

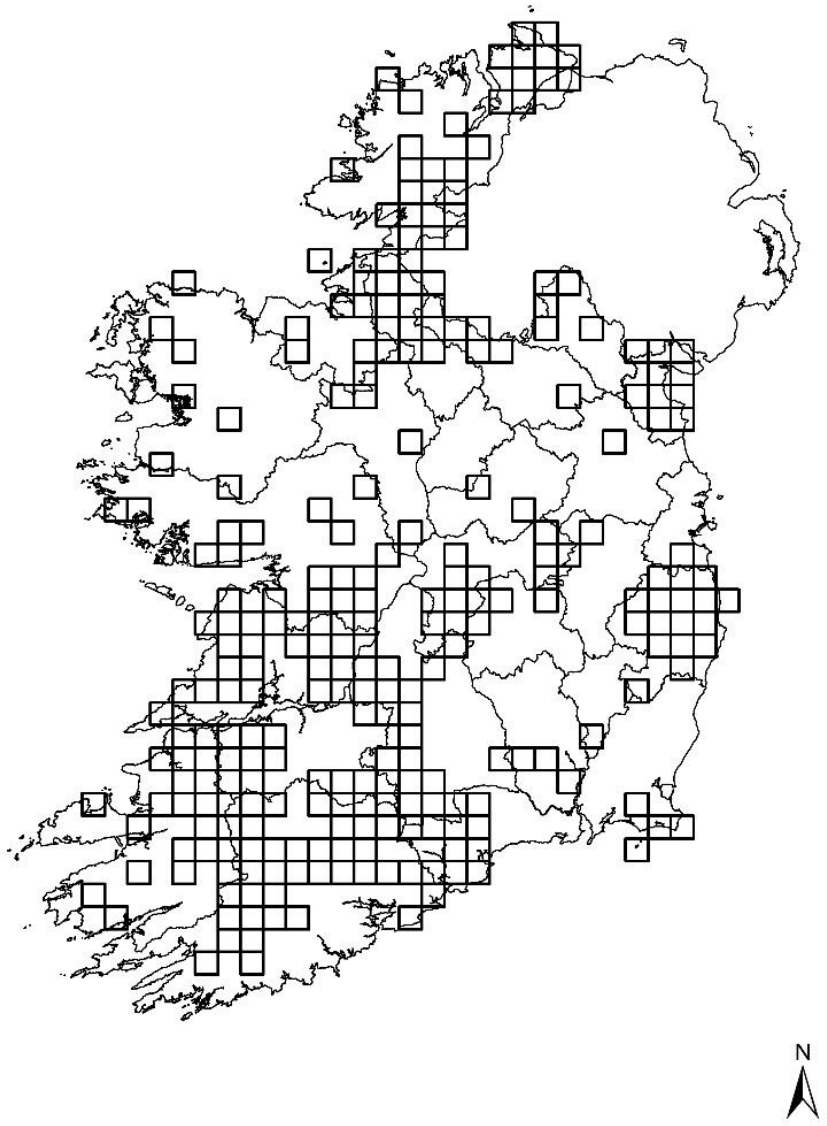
There was on-going allocation of squares throughout the survey period in order to increase coverage where additional volunteer or project team coverage was available, which resulted in the submission of data from 270 squares, although 19 of these were additional to the squares initially identified for coverage (Figure 1). Therefore from the initial 308 identified survey squares, 251 squares received at least one visit.

During initial field visits, 42 squares were identified as unsuitable during ground truthing and/or no longer suitable for breeding hen harriers. On this basis there were 23 squares which were excluded from further survey and an additional 25 squares were classified as marginal for breeding hen harriers. A high level of final coverage was obtained with all 'green' squares (100%) being surveyed along with 82.1% for 'yellow' squares, 73.3% of 'orange' squares and 66.7% of 'red' squares which is an increase from 2010 (85.4%, 51.6%, 51.1% and 33.8% respectively).

There were some data which were not submitted for allocated squares (19 squares) in time for inclusion in analyses, but it is understood that none of these data included any known additional breeding records of hen harriers. Whilst data were also received for another 19 squares not identified in the initial review, only one of these resulted in a confirmed breeding record, with other squares recorded as seen only (14 squares) or not seen (4 squares) records.

Whilst random squares were allocated during surveys, coverage was incomplete on these and some data on effort (hours) in other squares were not received for inclusion prior to reporting. A large sample of random squares (n = 125) for which data was received had some coverage (n = 104) but many of these did not receive all three visits as required by methodology (Visit 1: 62.5%; Visit 2: 85.6% & Visit 4: 50%; whilst other squares received effort during Visit 3: 51.9%) and thus further interrogation is required to produce a statistically derived population estimate and confidence intervals with appropriate caveats and are not being considered further in this report.

Figure 2. Distribution of survey squares covered during 2015 and for which data was received.



3.2 Survey effort and observations

There were 4,190 records submitted to the national database in 2015 which is a 54.5% increase from the 2,712 records received in 2010 (Ruddock *et al*., 2012). These records were derived from 3,296 visits which included vantage point observations, research observations (e.g. licensed nest visits) and casual observations. Records submitted were from 31st January to 22nd October with many records coming via the online recording forms which were verified by project co-ordinators where necessary. There were 18 records excluded from analyses as these were outside the breeding season (March – August, see Ruddock *et al*., 2012).

There was a minimum total of 3,296 visits undertaken to survey squares with a minority carried out before or after the defined breeding season (7.3%, n = 18). Survey visits to squares were undertaken according to the proposed schedule of visits (Table 1). There were 62.1% (n = 641; range 0 – 26 visits) completed during visit one (March – mid-April); 81.0% (n = 1,089; range 0 – 44 visits) during visit two (mid-April to mid-May); 53.9% (n = 585; range 0 – 35 visits) during visit three (mid-May – mid June) and 56.9% (n = 963; range 0 – 72 visits) during visit four (mid-June – end-July/August).

Survey effort during 2015 comprised a minimum of 7,225 hours 37 minutes which is a 76.9% increase from survey effort in 2010 (4,074 hours 26 minutes; Ruddock *et al*., 2012) and a 260.2% increase from survey effort in 2005 (2,006 hours; Barton *et al*., 2006). Vantage point observation and casual sightings were undertaken between 0535h and 2230h and observations ranged in duration from five minutes to 8 hours 5 minutes with an average duration of 2 hours 18 minutes (median 2 hours 30 minutes).

During vantage points observations there were between zero and 30 observations of hen harriers per watch and 2,222 total detections of hen harrier. The majority of hen harrier sightings were adult males (1 – 3 birds) and adult females (1 – 2 birds), juveniles (1 – 5 birds) and an increased number of immature males was recorded since 2010 (Table 6 & Table 7). The majority of sightings (84.4%; n = 1,875) were assigned to at least one behaviour category (Table 8) and at least one habitat (96.7%, n = 2,149; Table 9).

Similar to 2010 (Ruddock *et al*., 2012) the key behaviours observed (Table 8) were flying (29.9%) and hunting (16.6%) with sightings most frequently detected in heather moorland (36.1%) and second rotation forest (22.4%). The total frequency of observations in open habitats (see Footnote in Table 9) in 2015 increased marginally to 49.8% from 44.8% in 2010. Another notable difference was that fewer sightings were recorded in forested habitats in 2015 (42.7%) compared to 2010 (49.4%) although none of these differences were significantly different between survey years (2010 & 2015; $X^2 = 0.6491$; $p = 0.42$; NS).

Further examination of hunting (foraging) behaviours (Table 10) and associated habitats reveal a similar pattern to 2010 observations with hen harriers most frequently recorded foraging over heather moorland (30.0%) and second rotation forest (18.7%), followed by rough grassland (12.4%) and thicket stage forest (12.4%). The frequency of foraging detections in first rotation forests decreased since 2010 (12.1% to 7.7%) but frequency of hunting recorded in both rough grassland and thicket forest increased (Table 9 & 10; see Ruddock *et al*., 2012). During 2015 the recorded use of habitats for foraging was greater in open habitats (51.3%) than afforested habitats (40.6%) which is similar to frequencies recorded in 2010 (53.4% and 42.5% respectively) and which is not significantly different between survey years (2010 & 2015; $X^2 = 0.0861$; $p = 0.77$; NS).

'Linear features' was a new foraging habitat category added since the previous national surveys, to which a small number of records were assigned (1.2%) which included birds utilising drainage channels, hedgerows, forest rides and open habitat corridors containing power-lines.

Table 6. Summary of sightings of hen harriers categorised by age and/or sex. 2010 figures are shown in parentheses

Sex/age	Total Observations	Number of birds
Adult male	1223 (943)	1247 (973)
Adult female	1066 (865)	1084 (890)
Immature male	120 (50)	120 (50)
Juveniles	378 (110)	671 (213)

Table 7. Summary of sightings of hen harriers categorised by age and/or sex

Sex/age	Total Observations	Total number of birds
Adult male only	780	792
Female only	588	597
Immature male only	71	71
Juveniles only	255	415
Male(s) & Female(s)	359	371 & 365
Male & Immature & female	8	8 & 9 & 8
Immature male & female	29	30 & 29
Immature male & adult male	9	10 & 9
Female & juvenile	54	55 & 105
Male & juvenile	38	38 & 84
Pair & juvenile	28	56 & 63

Table 8. Summary of behaviours observed during sightings of hen harriers. 2010 figures are shown in parentheses

Behaviour	Observations (n)	Occurrence (%)
Displaying	152 (155)	4.4 (7.2)
Food pass	245 (183)	7.1 (8.5)
Hunting	573 (392)	16.6 (18.2)
Flying	1035 (512)	29.9 (23.8)
Alarming	39 (80)	1.1 (3.7)
With prey	163 (98)	4.7 (4.6)
Soaring	175 (159)	5.1 (7.4)
Circling	275 (225)	8.0 (10.5)
Perched	163 (83)	4.7 (3.9)
On ground	170 (78)	4.9 (3.6)
Mobbing	46 (44)	1.3 (2.0)
Other	207 (153)	6.0 (7.1)

Table 9. Summary of habitats in which hen harriers were observed with 2010 figures shown in parentheses.

Habitat type	Occurrence (n)	Occurrence (%)
*First rotation forest (1F)**	138 (213)	5.2 (13.1)
*Second rotation forest (2F)**	591 (346)	22.4 (21.3)
*Thicket (T)**	362 (185)	13.7 (11.4)
*Clearfell (CF)**	38 (58)	1.4 (3.6)
Heather moor (H)$	954 (473)	36.1 (29.1)
Grass moor (G)$	94 (54)	3.6 (3.3)
Rough grazing (RG)$	221 (92)	8.4 (5.7)
Improved grazing (IG)$	48 (38)	1.8 (2.3)
Scrub (S)	85 (71)	3.2 (4.4)
Linear features associated with rough grassland (LR)	26 (-)	1.0 (-)
Linear feature associated with improved grassland (LI)	5 (-)	0.2 (-)
Other (O)	82 (94)	3.1 (5.8)
Total	2644 (1624)	

* These habitats are combined to provide a cumulative estimate for afforested habitats
$ These habitats are combined to provide a cumulative estimate for open habitats

Table 10. Summary of habitats in which hen harriers were observed hunting, with 2010 figures shown in parentheses.

Habitat type	Occurrence (n)	Occurrence (%)
First rotation forest (1F)	63 (60)	7.7 (12.1)
Second rotation forest (2F)	154 (83)	18.7 (16.8)
Thicket (T)	102 (44)	12.4 (8.9)
Clearfell (CF)	15 (23)	1.8 (4.7)
Heather moor (H)	247 (168)	30.0 (34.0)
Grass moor (G)	57 (21)	6.9 (4.3)
Rough grazing (RG)	102 (40)	12.4 (8.1)
Improved grazing (IG)	16 (16)	1.9 (3.2)
Scrub (S)	22 (19)	2.7 (3.8)
Linear features associated with rough grassland (LR)	16 (-)	1.9 (-)
Linear feature associated with improved grassland (LI)	3 (-)	0.4 (-)
Other (O)	26 (20)	3.2 (4.0)
Total	823 (494)	

3.3 National and regional population estimates, population change and breeding density

The 2015 survey identified 108 confirmed and 49 possible breeding territories, which provides a composite national population estimate of 108 – 157 breeding pairs. This equates to an 8.7% decrease from the 2010 survey maximum population estimate (128 – 172 pairs; Ruddock *et al.*, 2012; see Table 11) and similar to the population estimate in 2005 (132 – 153 pairs; Barton *et al.*, 2006) but higher than the 1998 – 2000 estimate (102 – 129, Norriss *et al.*, 2002) (Table 11). Comparison of the mid-point values provides an overall means of assessing population change which is -11.7% and helps minimise bias associated with increasing survey effort (Figure 3) on the estimated population range. There were 8 – 10 confirmed plus possible pairs located in border counties of Northern Ireland, where squares covered both jurisdictions which are not incorporated into this estimate.

Table 11. National (minimum, maximum and mid-point) population estimates between 1998-2000 (Norriss *et al.*, 2002); 2005 (Barton *et al*., 2006); 2010 (Ruddock *et al*., 2012) and this study (2015).

Breeding status	1998-2000	2005	2010	2015	% change 2010 – 2015
Confirmed	102	132	128	108	-15.60%
Possible	27	21	44	49	11.36%
Confirmed + possible	129	153	172	157	-8.7%
Mid-point	115.5	142.5	150	132.5	-11.7%
Range	**102 - 129**	**132 - 153**	**128 - 172**	**108-157**	-

Confirmed breeding pairs were recorded in 62 squares (similar to 2010) (Figure 4) and possible breeding pairs in 22 squares (increased from seven in 2010), indicating a 21.7% increase in the recorded breeding range compared with the previous national surveys (Table 12). The aforementioned increased survey effort may also partly explain this observed increase. There were 56 squares classified as 'seen', which represents an increase over the national survey period (25 in 2010; 21 in 2005 and 21 in 1998 – 2000; Figures 4 & 5).

There were between one and seven confirmed pairs recorded per 10km square and between one and two possible pairs per 10km square. The maximum number of pairs recorded in a 10km square nationally during 2015 was seven compared to a maximum of nine in 2010. There were regional changes observed in both confirmed and possible distributions in 2015 (Figure 6) and between surveys (Figures 7 – 9) which resulted in few nett changes in most areas but with increases or decreases in some areas (Figure 10) and changes recorded in many regional areas (Table 13).

Table 12. Number of 10km squares by breeding hen harrier status in Ireland during survey periods.

Breeding status	1998-2000	2005	2010	2015	% change 2010 - 2015
Confirmed	42	60	62	62	0.0%
Possible	17	6	7	22	214.3%
Range	**42 - 59**	**60 - 66**	**62 - 69**	**62 - 84**	-

A subset analysis was carried out on 139 10km squares which were covered in both 2010 and 2015 surveys and revealed some acute declines with up to six pairs lost in some squares (Figure 11). Within these 139 10km squares, 127 confirmed pairs were recorded in 2010, compared to 100 confirmed pairs in 2015, representing a decline of 21.2% over this five year period. A similar number of possible pairs were recorded within this subset across both survey years (44 in 2010 compared with 43 in 2015). Therefore, the overall decline of confirmed plus possible breeding pairs within the subset of 139 10km squares covered in both the 2010 and 2015 surveys was 16.4%.

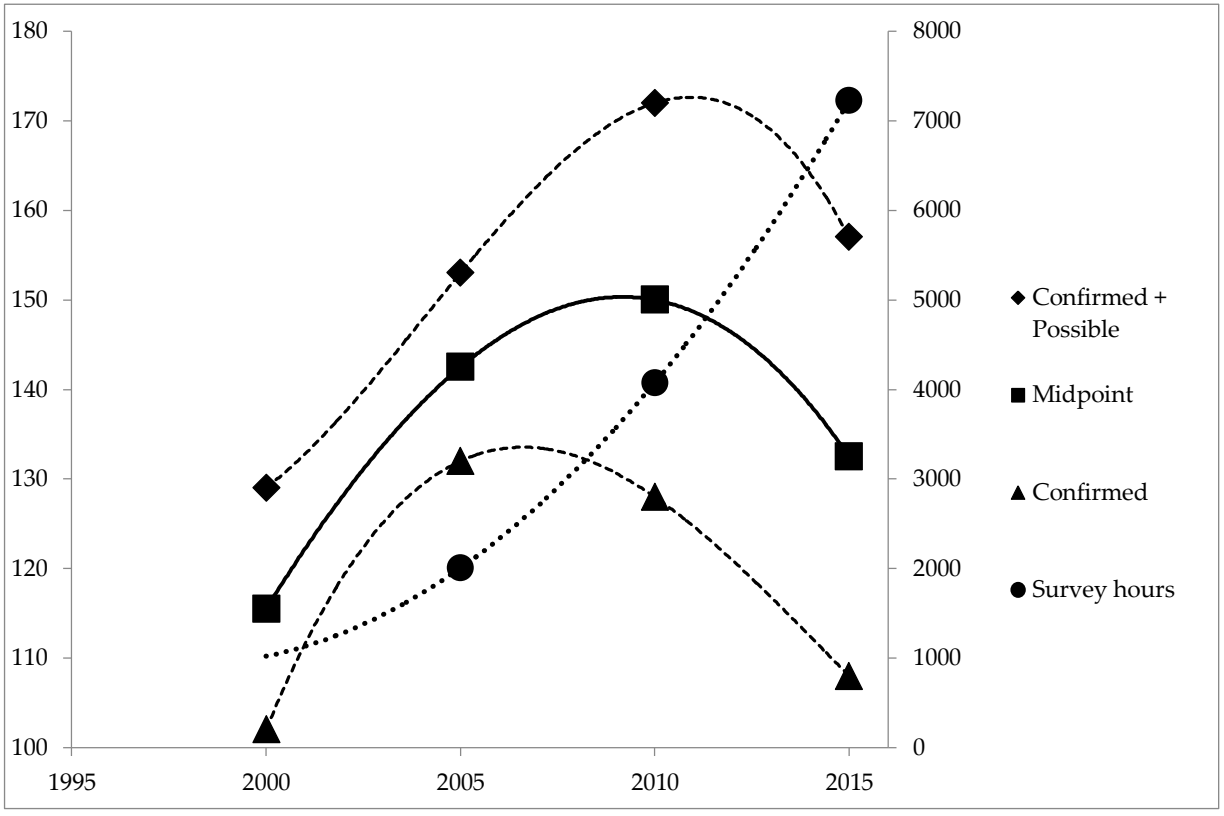
The subset analysis carried out in 2010 of 113 squares covered in both 2005 and 2010 surveys (see Ruddock *et al*., 2012) was also re-analysed in 2015. Data were only received for 110 of these 113 squares in 2015 but the three squares not covered had not previously contained any breeding pairs during any

of these three national surveys. Comparison of these 110 squares across years found 95 – 130 pairs in 2015 compared to 117 – 156 pairs in 2010 and 125 – 144 pairs in 2005 (Figure 12).

The confirmed pairs in these squares have thus declined by 18.8% since 2010 while possible pairs have declined by 10.2%. There has been a 24% decrease in confirmed pairs in these squares since 2005 and an 84% increase in possible pairs since 2005. Overall the total population (i.e. confirmed plus possible pairs) appears to have declined in this subset of squares by 16.7% (156 to 130 pairs) since 2010 and by 9.7% since 2005 respectively but with an 8.3% increase between 2005 and 2010 (Figure 12).

In an analysis of the subset of squares covered during 1998 – 2000, 2005, 2010 and 2015 to derive a longer term trend (Figure 13). There were 78 squares with data which covered during all four survey periods. Within these 78 squares in 1998 – 2000, there were 110 – 155 pairs which declined in 2005 to 110 – 127 pairs (-18.1%) with a small increase recorded in 2010 to 100 – 132 pairs (+3.9%) and finally a decline in 2015 to 78 – 103 pairs (-21.9%). Overall from 1998 – 2000 there has been a decrease by approximately one third (-33.5%) in these squares which have received coverage across all surveys. Losses have been particularly noted in the south-west over this period (Figure 13; see also O'Donoghue *et al*., 2011; O'Donoghue, 2012).

Figure 3. Graph showing the recorded population range and mid-point estimates, trendlines and survey effort over the national hen harrier surveys.



Footnote: No value for survey hours was available for the 1998 – 2000 dataset and thus only the hindcasted trend predicted value is shown above

Figure 4. Distribution of breeding hen harriers in Ireland within 10km squares surveyed during 2015, classified by breeding status.

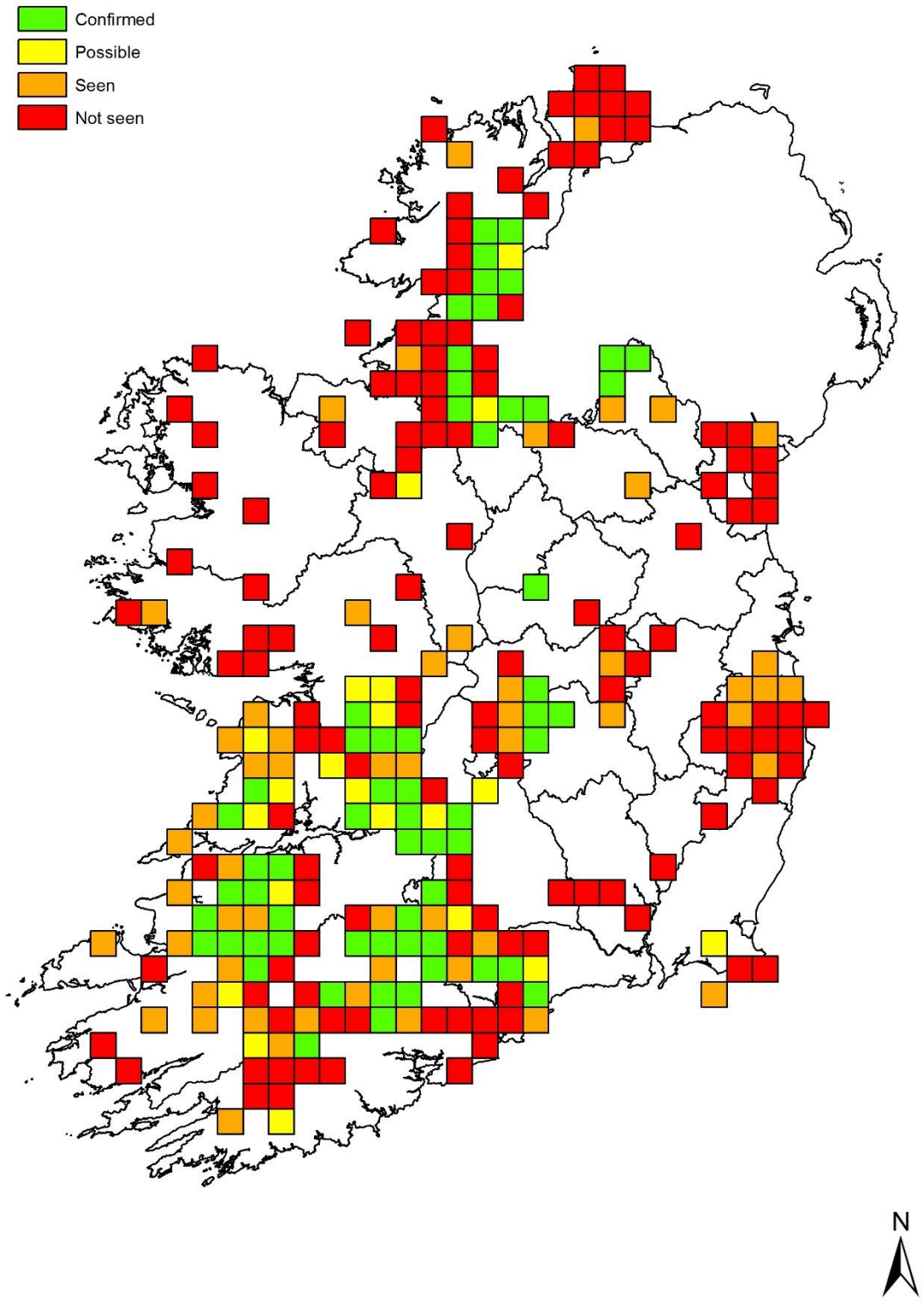


Figure 5. Distribution and breeding status of the hen harrier between year comparisons i) 2015; ii) 2010; iii) 2005 and iv) 1998 – 2000.

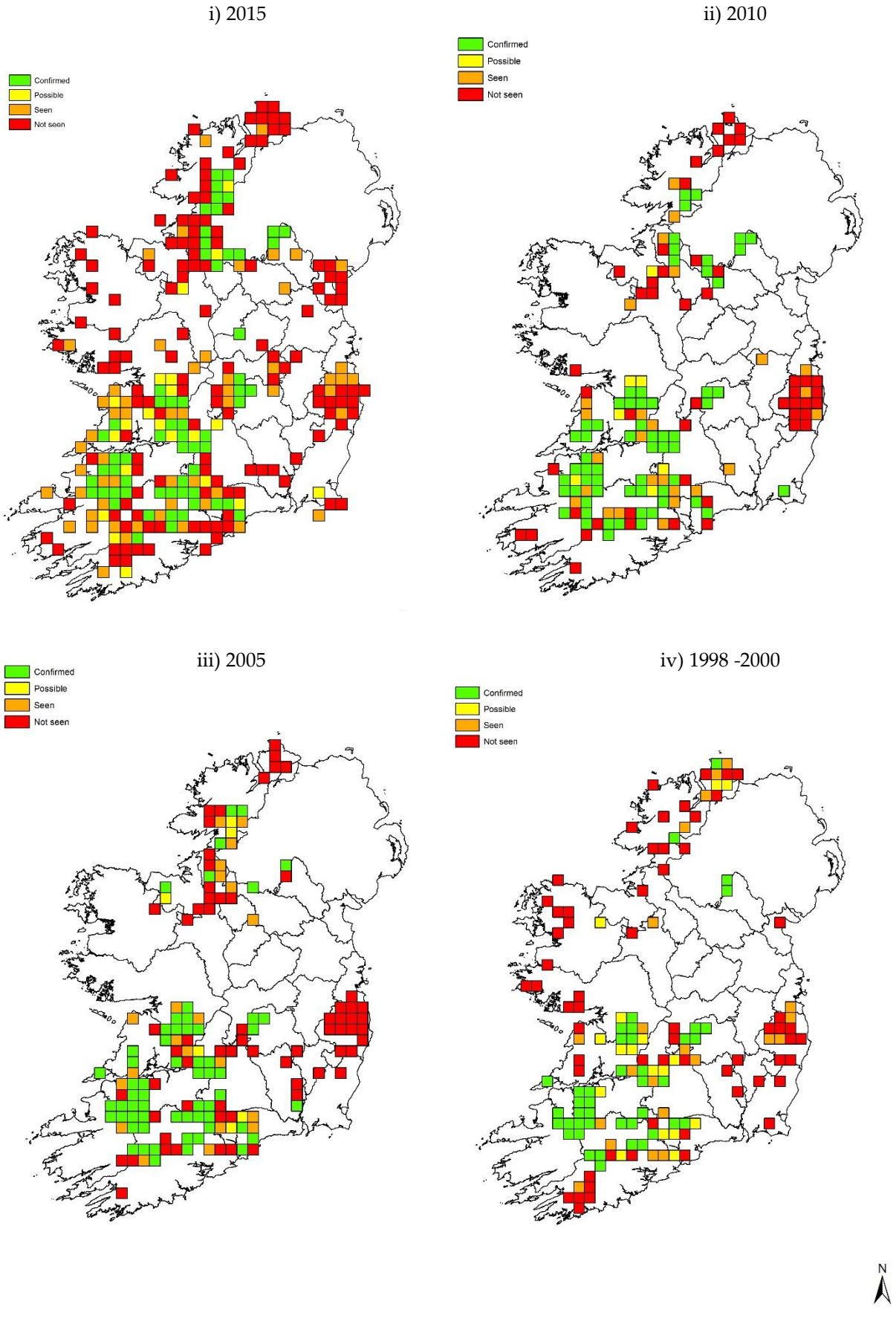


Figure 6. The distribution and numbers of confirmed and possible breeding hen harrier in Ireland during 2015. Black squares show total number of pairs (confirmed + possible) and grey squares show total number of pairs (possible only).

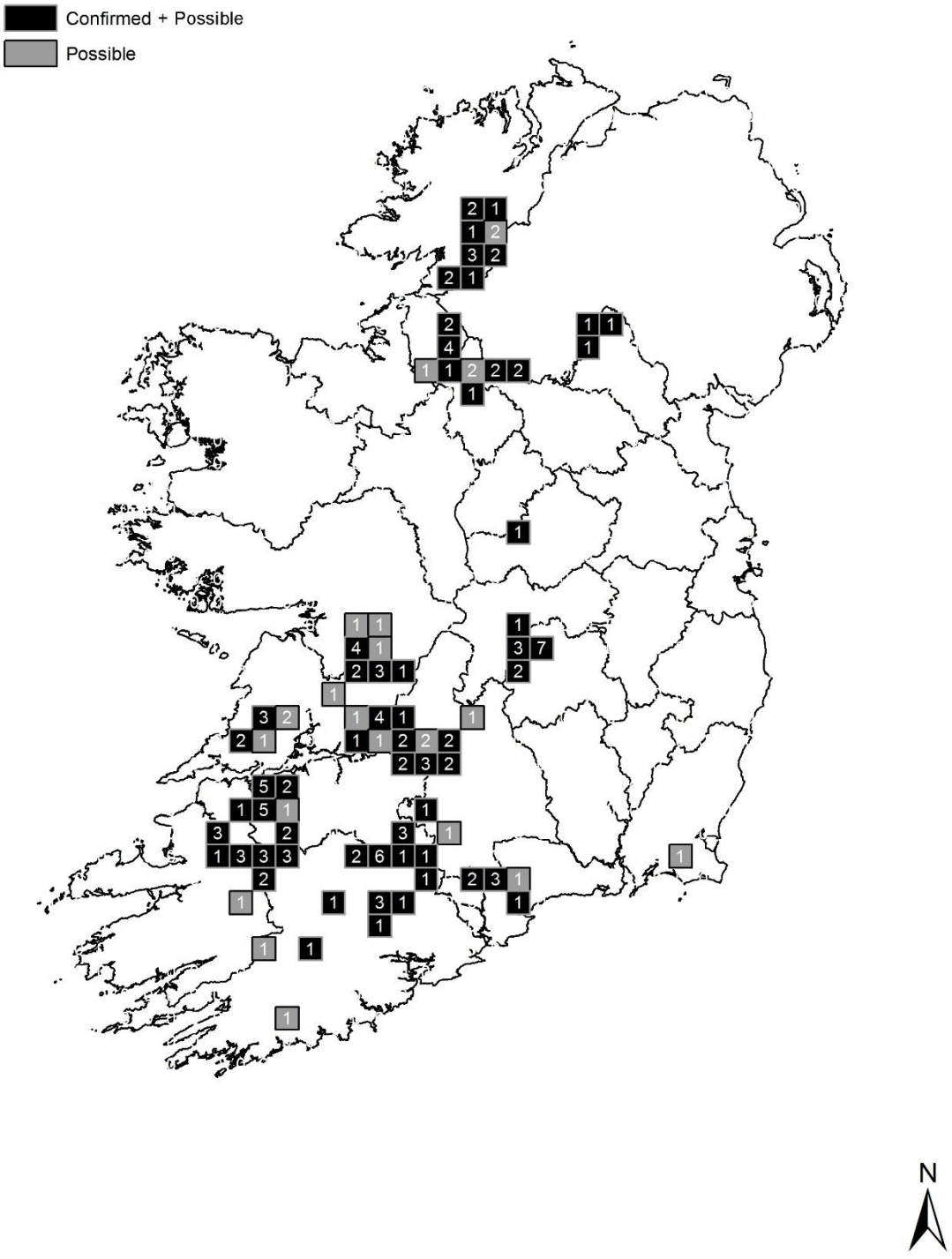


Figure 7. The changes in distribution and numbers of breeding hen harrier in Ireland between 2010 and 2015 and histogram showing frequency of numerical changes.

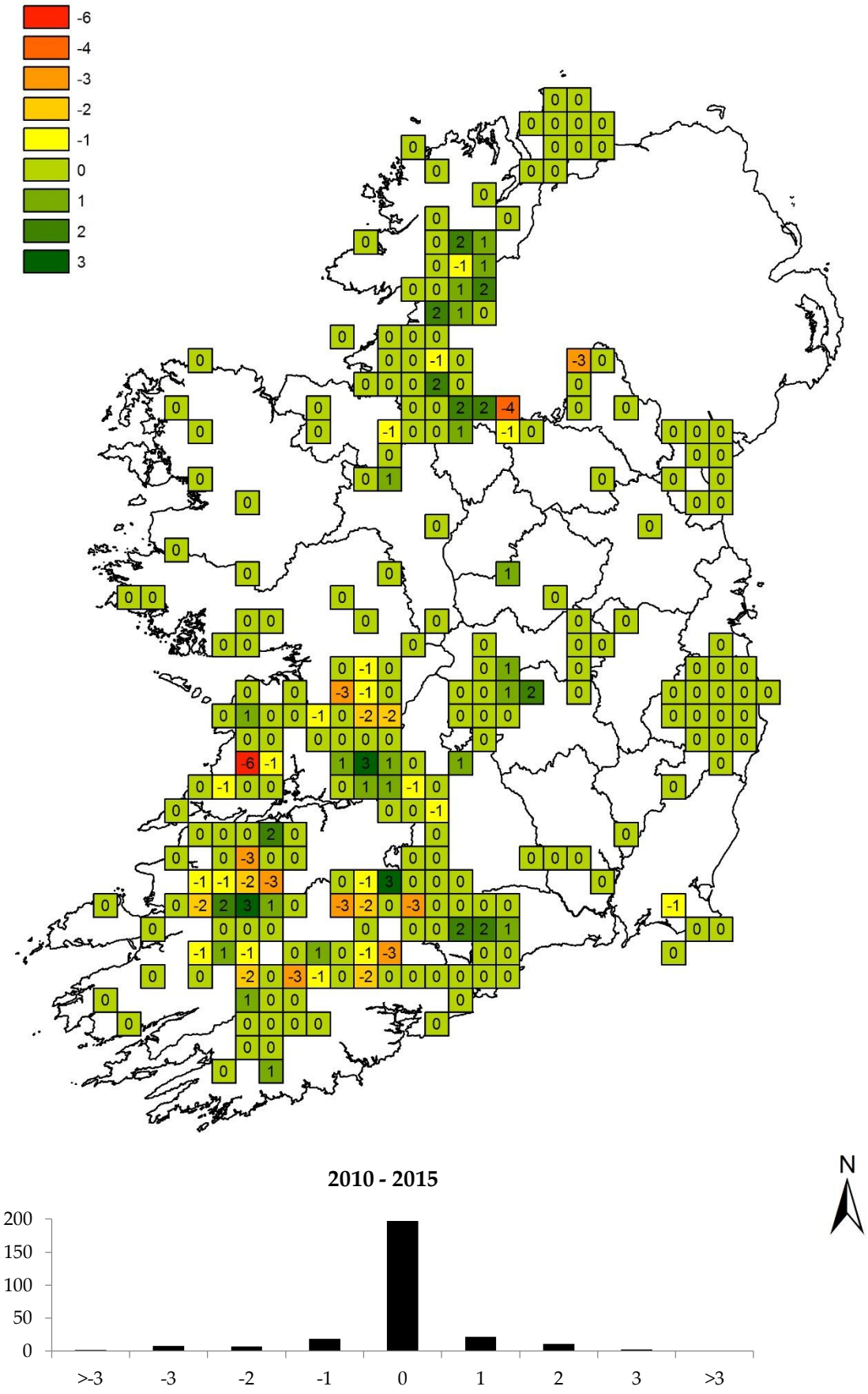


Figure 8. Maps showing stability, increase and/or decrease between surveys in 2005 and 2015 and histogram showing frequency of numerical changes.

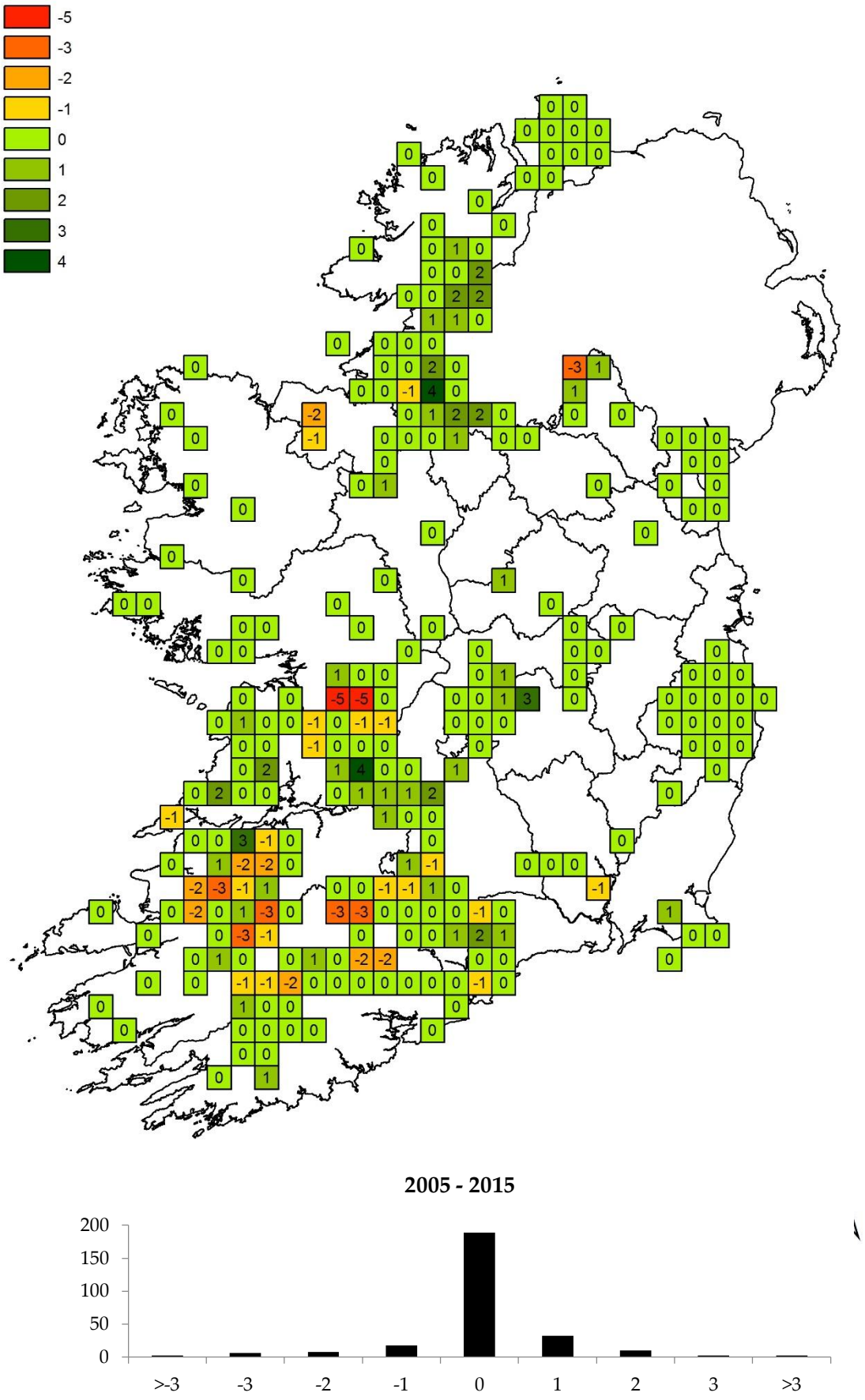


Figure 9. Maps showing stability, increase and/or decrease between surveys in 1998 - 2000 and 2015 and histogram showing frequency of numerical changes.

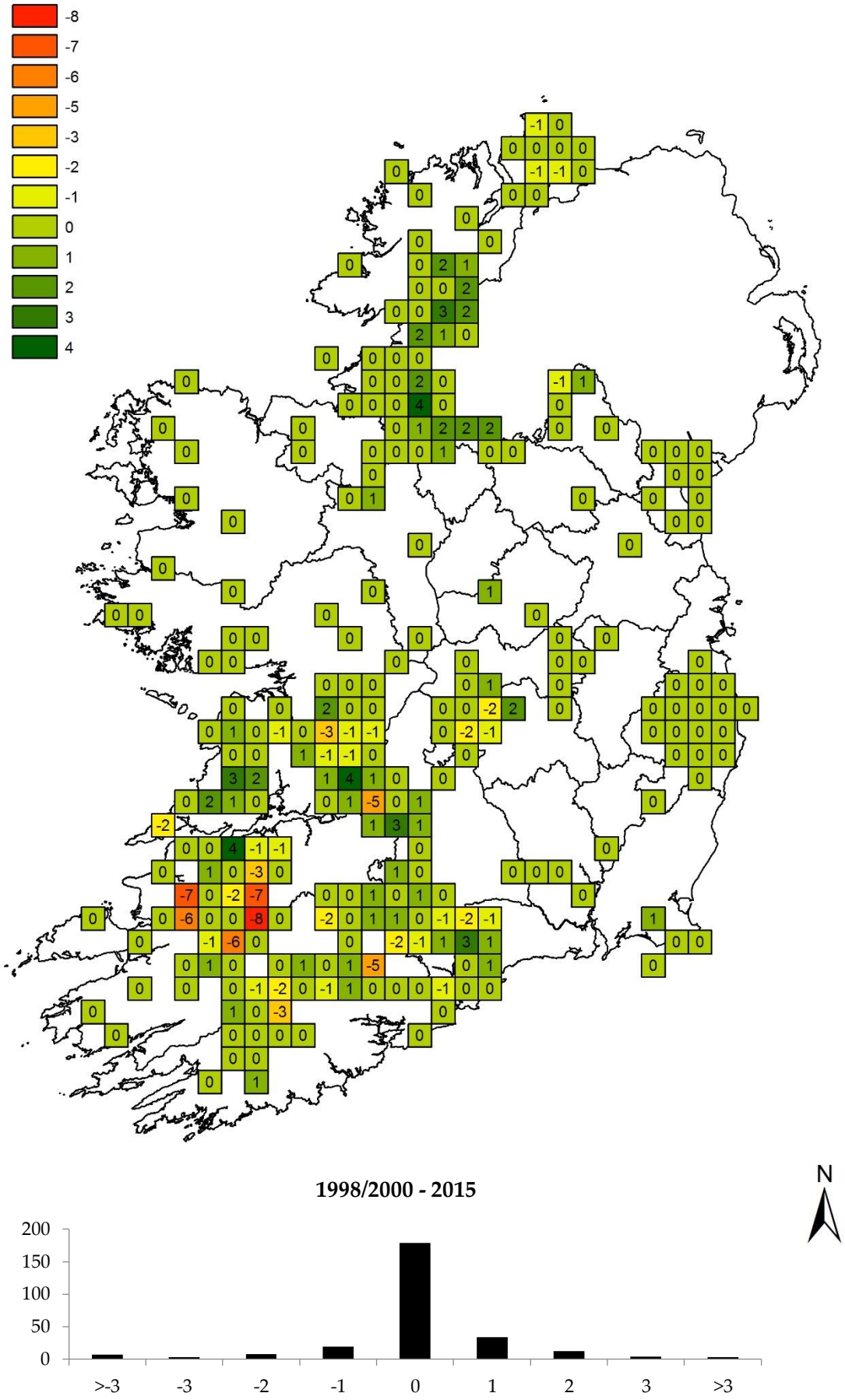


Figure 10. The changes in distribution and numbers of breeding hen harrier in Ireland between 2010 and 2015 showing direction of change in numbers.

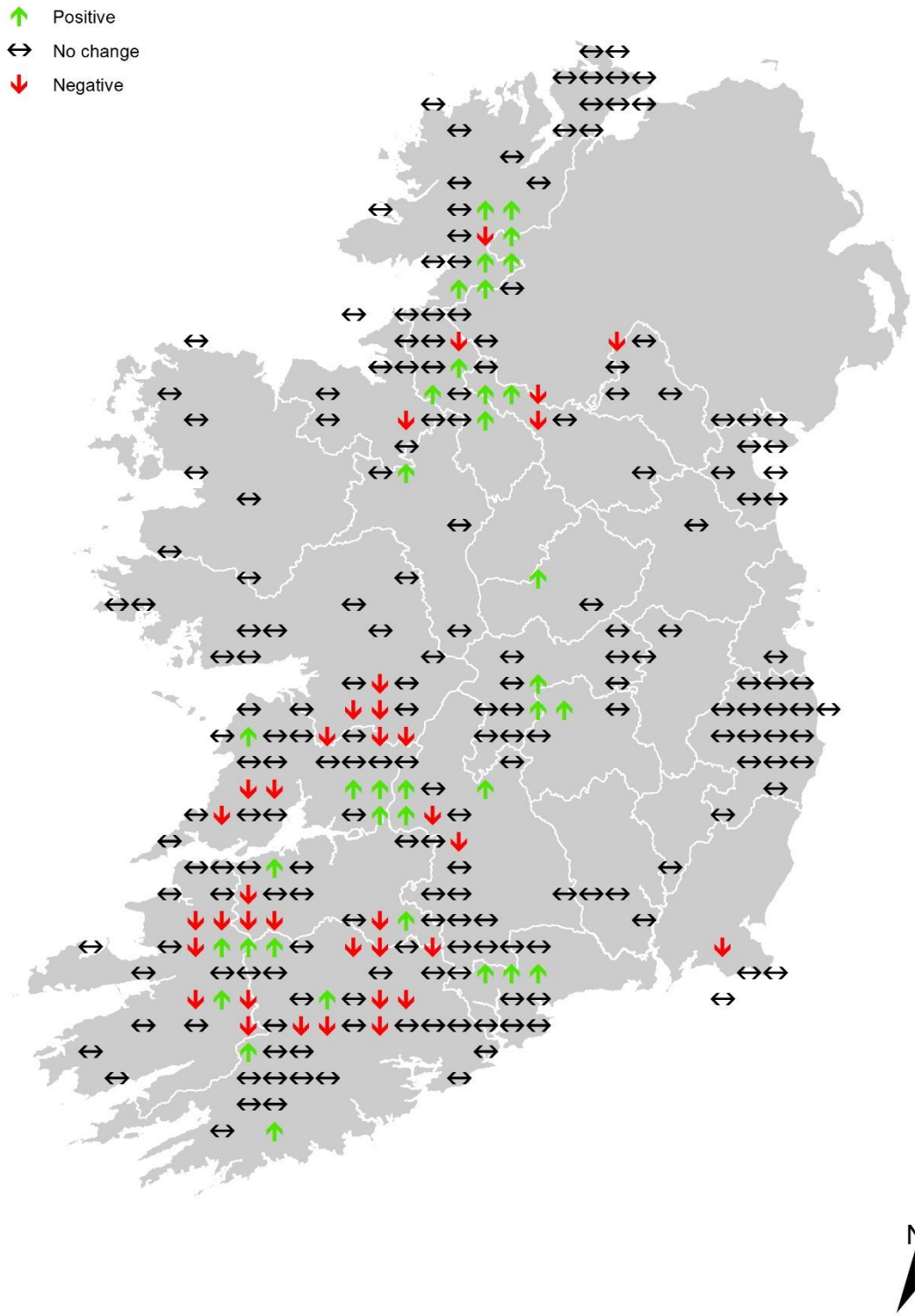


Figure 11. The changes in distribution and numbers of breeding hen harrier in Ireland between 2010 and 2015 in the subset of squares (n = 139) surveyed in both 2010 and 2015.

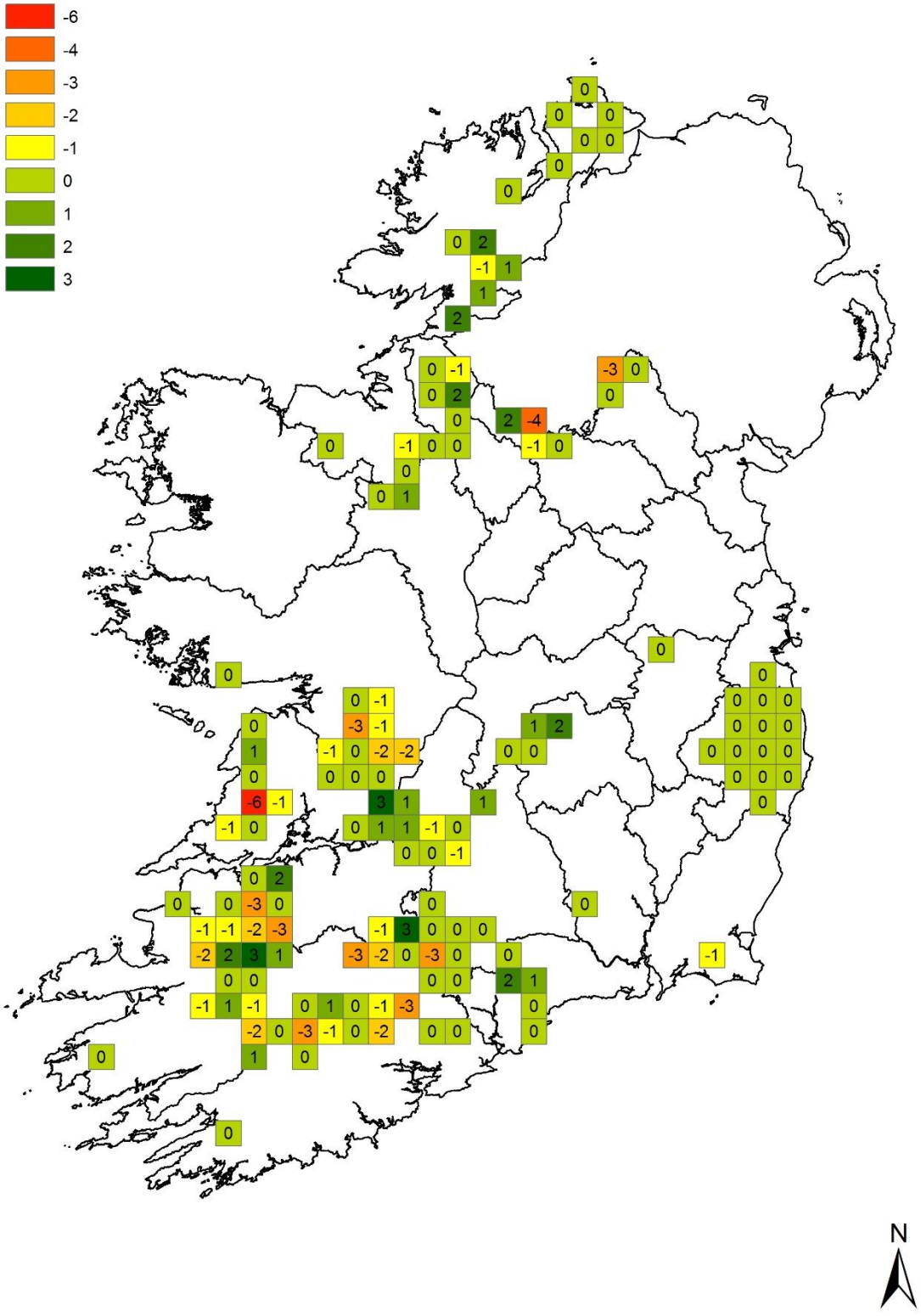
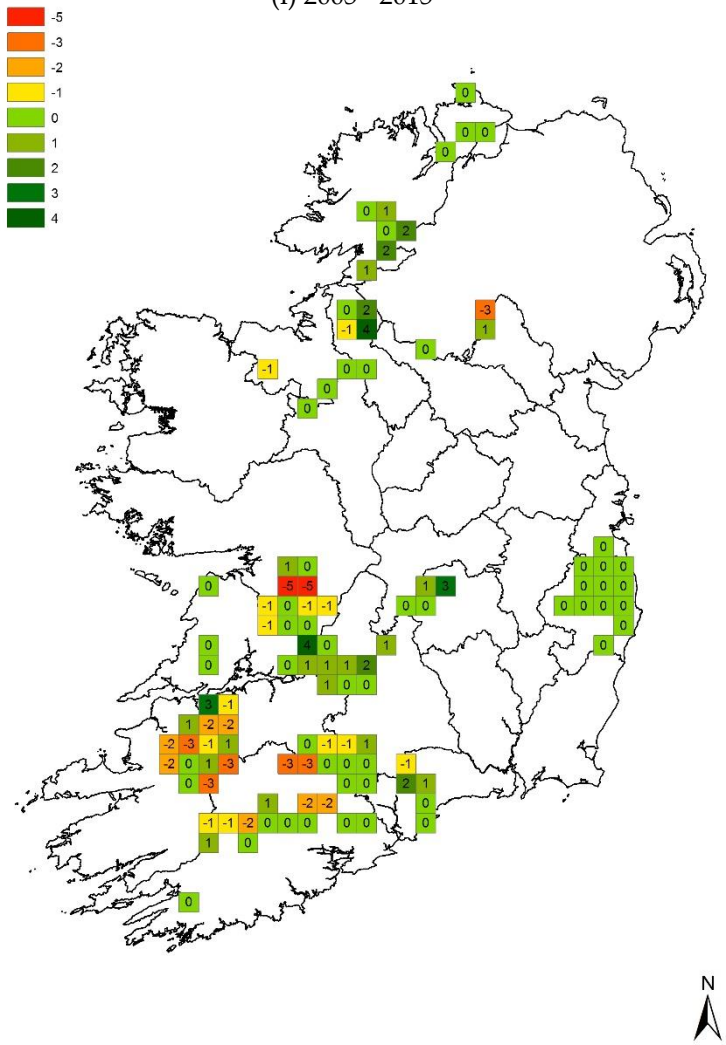


Figure 12. The changes in distribution and numbers of breeding hen harrier in Ireland between (i) 2005 - 2015 and (ii) 2010 - 2015 in the subset of squares (n = 110) surveyed in 2005, 2010 and 2015.

(i) 2005 - 2015



(ii) 2010 - 2015

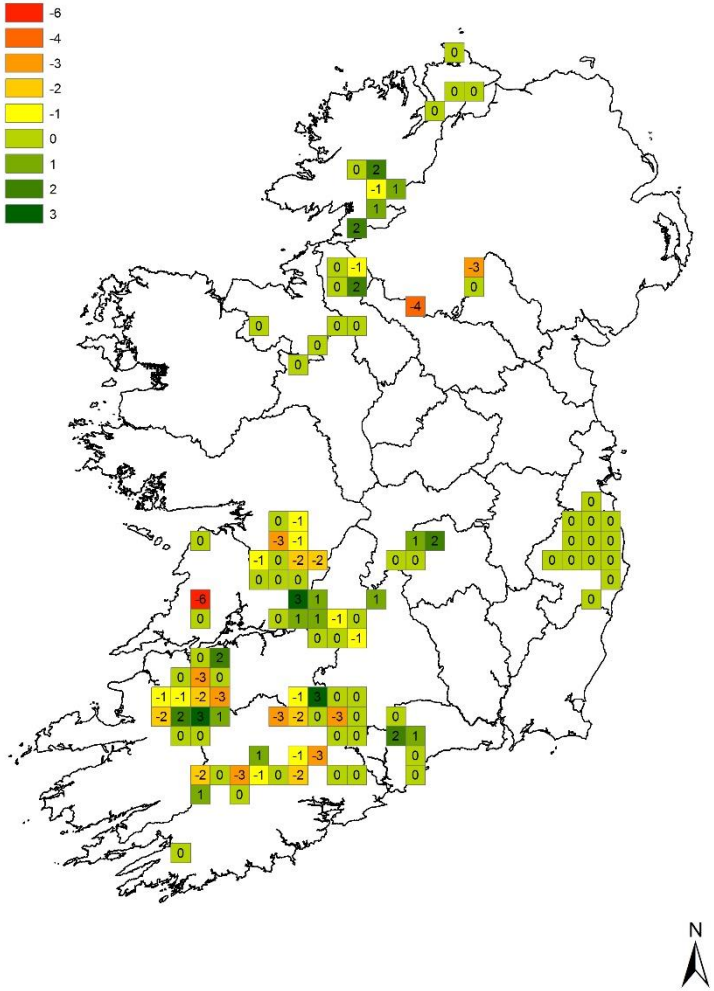


Figure 13. The changes in distribution and numbers of breeding hen harrier in Ireland between (i) 1998-2000; (ii) 2005; (iii) 2010 and 2015 in the subset of squares (n = 78) surveyed in 1998-2000, 2005, 2010 and 2015

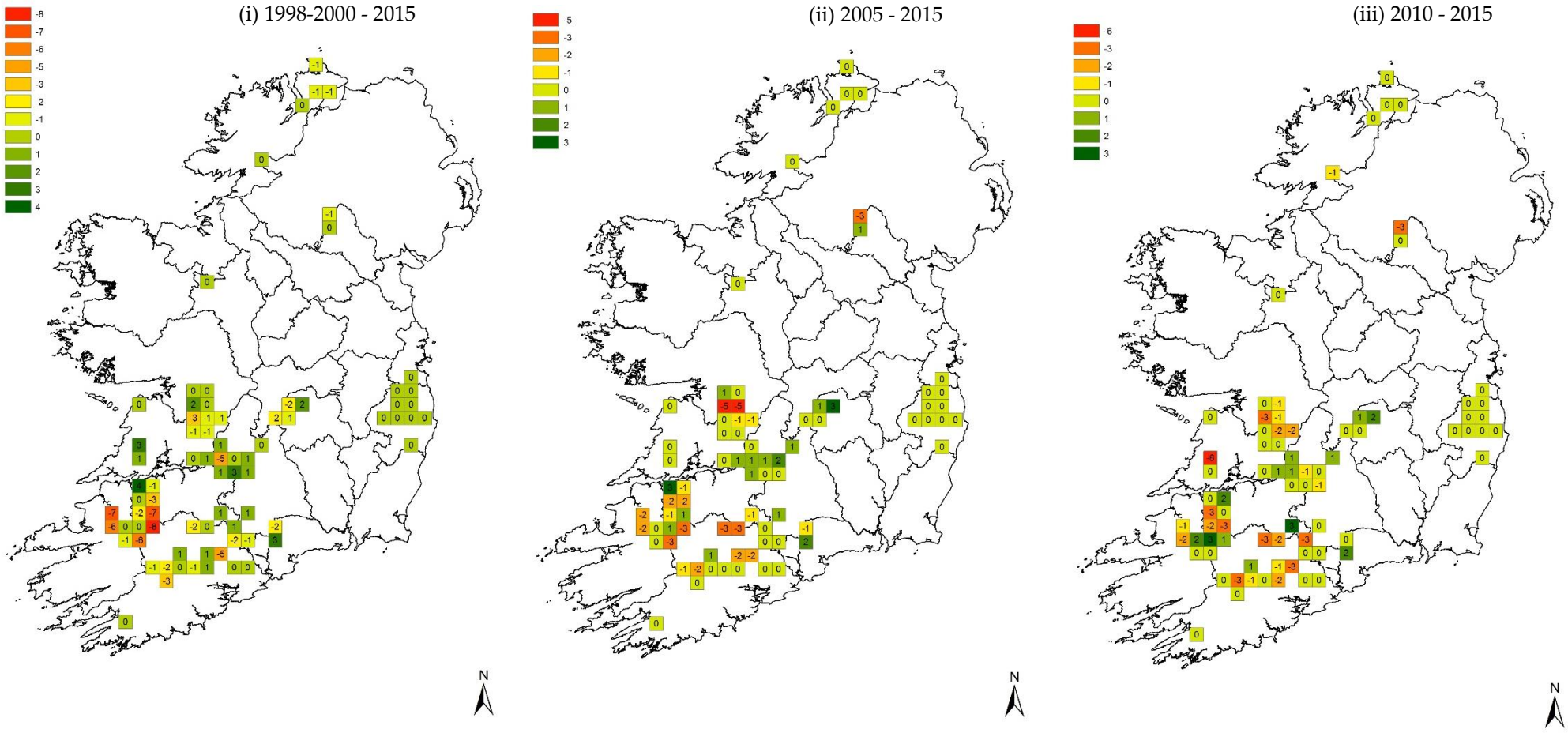


Table 13. Regional population estimates during 2015 utilising the squares as defined in 1998-2000, 2005 and 2010 for regional mountain ranges or site complexes.

Region	*Total pairs 1998 - 2000*	*Total pairs 2005*	*Total pairs 2010*	*Total pairs 2015*
Ballyhouras	*6-8*	*17-19*	*10-15*	*10-12*
Blue Stack Mountains, Pettigo Plateau & South Donegal	*1*	*3-5*	*4-5*	*8-12*
Boggeraghs, Derrynasaggarts	*4-5*	*5*	*6-8*	*2-4*
Castlecomer, Blackstairs, Kilkenny	*0*	*1*	*0*	*0*
Curlew Mountains	-	-	*0*	*0*
*Devilsbit, Slievefelim, Silvermines, King Hill**	*5-7*	*7-8*	*10-14*	*7-15*
East Cork & Waterford	*0-1*	*2*	*1*	*1*
Galtys	*0*	*3*	*5-6*	*2-3*
Inishowen Peninsula	*1-3*	*0*	*0*	*0*
Kildare	-	-	*0*	*0*
Knockmealdowns, Kilworth, Comeraghs	*3-7*	*2-4*	*2*	*5-7*
Leitrim, Slieve Rushen, Cavan	*0*	*3*	*12-14*	*9-15*
Longford, Roscommon	*0*	*0*	*0 - 1*	*0-1*
Nagles	*3-5*	*9*	*7-11*	*5*
North & West Clare	*1-2*	*5*	*12-16*	*3-9*
North West	-	-	*0*	*0*
Ox Mountains, Sligo	*0 - 1*	*1-3*	*0*	*0*
Slieve Aughties	*10-21*	*24-27*	*16-24*	*8-14*
Slieve Beagh	*3*	*4*	*5-6*	*3*
Slieve Bernagh to Keeper Hill	*1*	*1-2*	*2*	*5-7*
Slieve Blooms	*10-11*	*5-8*	*9*	*11-12*
Stack's, Glanarudderies, Knockanefune, Mullaghareirks, North of Abbeyfeale	*38-45*	*40-45*	*25-36*	*25-31*
West Cork	*0*	*0*	*0*	*0-1*
West Kerry	-	-	*0*	*0*
Wexford	-	-	*1-2*	*0-1*
Wicklow Mountains	*0*	*0*	*0*	*0*
*Other areas***	-	-	*0*	*4*
Total numbers	*102-129*	*132-153*	*128 - 172*	*108-157*

**The Keeper Hill area is in close proximity to the Slievefelims and has been included within the Devilsbit, Slievefelim, Silvermines and King Hill complex and not the Slieve Bernagh – Keeper Hill area in previous surveys. For the purposes of regional comparisons between surveys the same regional groups have been maintained. ** Includes one territory immediately north of Slieve Blooms and within SPA but not in previously defined square*

Nationally there is a decline in the hen harrier population since 2010, however in regional analyses it is shown that both declines and/or increases have occurred (Table 13). The Ballyhouras appears stable since 2010, although numbers are lower than in 2005 but higher than 1998 – 2000 surveys. In Donegal, the Blue Stacks, Pettigo and south Donegal areas have largely recorded increases compared with all previous surveys (Table 13; Figure 10) although a small number of losses in squares were recorded and thus movements may account for at least some of the recorded increases in this area. Undoubtedly increased effort in this area in 2010 and again in 2015 has recorded some genuine increases as well as some previously undocumented breeding locations.

The Devils Bit – Slievefelim - Silvermines – King Hill complex appears relatively stable since 2010. However, there has been an approximate doubling in the numbers recorded in this area from the 2005 and 1998 – 2000 surveys in both 2010 and 2015. At Slieve Bernagh to Keeper Hill numbers were greatly increased, and were more than double that recorded for any of the previous surveys, whilst the Stacks, Glanarudderies, Knockanefune, Mullaghareirks, north of Abbeyfeale complex appears relatively stable since 2010 (25 – 36 to 25 – 31) but remains much decreased since both 1998 – 2000 and 2005 population estimates.

There were recorded declines in the Galty Mountains since 2010 and an increase has been recorded since 2010 in the Knockmealdowns – Kilworth Hills – Comeraghs. This overall increase in this complex is due to an increase in the Knockmealdowns population with increased survey coverage in that range which discovered additional pairs. In the Leitrim – Slieve Rushen – Cavan area an overall increase has been recorded although this is due to a much greater increase in the Leitrim sites since the Slieve Rushen sites have actually declined since 2010.

The Nagles contained a maximum of five breeding pairs which represents a decline from both 2005 and 2010 although similar to the estimate provided in 1998 – 2000. Overall north and west Clare has declined considerably since 2010 from the 12 – 16 pairs recorded, which represented the highest numbers for this area across all national surveys. The recorded declines since 2010 are primarily the result of reduced densities in occupied squares in west Clare, as increased activity was recorded in north Clare which held one possible pair in an area where breeding evidence has not been recorded in previous surveys. Despite declines since 2010, numbers recorded in north and west Clare have increased since the 2005 and 1998 – 2000 surveys.

Despite continued good coverage, an acute decline was recorded in the Slieve Aughty range, where the population was also observed to decline since 2005. In 2015 the recorded population was less than half of that recorded in 2005, and further substantial declines were observed since 2010. Some squares to the south of the Aughties did however show an increase in 2015 (Figure 10) which may be explained by redistribution.

At Slieve Beagh there has been a decline to three pairs which is one less than in 2005 (4 pairs) and a considerable decline from the 2010 figures (6 pairs). There has also been a concomitant shift in distribution with the traditional moorland pairs now apparently relocated to afforested areas or heather margins within or adjacent to forested areas.

Extensive surveys carried out in the Louth uplands revealed no territorial pairs and only a single sighting despite extensive suitable habitat. A single confirmed breeding pair was recorded in East Cork – Waterford and a single possible breeding pair each was recorded in West Cork and Wexford. Several areas had no recorded breeding hen harrier (Table 13) including; Castlecomer – Blackstairs – Kilkenny; Curlew Mountains; Inishowen Peninsula; Kildare; Ox Mountains; Sligo; West Kerry; and Wicklow – South Dublin Mountains. Whilst there was no confirmed breeding identified in the east region including south Dublin, Wicklow and Carlow, several squares have had sightings of both males and females (Figure 4) which were followed up closely by surveyors without further proof of breeding recorded.

The Slieve Blooms squares showed an increase since 2010 (from 9 to 11 – 12 pairs), with the highest numbers recorded in 2015 compared with past surveys. This represented a slight increase from the previous highest total in 1998 – 2000 (from 10 – 11 pairs in 1998 – 2000 to 11 – 12 in 2015). Survey effort in this area was exemplary and most pairs in this region are recorded to nest in moorland. An additional pair was also recorded in a square immediately to the north, which was not previously classified as part of the Slieve Blooms complex resulting in a maximum of 12 – 13 pairs in the Slieve Blooms area.

Despite apparent declines in some traditional strongholds, pairs have been recorded for the first time in some previously unrecorded areas (other areas in Table 13) including a pair recorded in east Clare. Sightings of a male and female were also observed in north Clare, which was recorded as a possible pair where no evidence of breeding has been previously recorded through the national surveys.

A small number of additional territories (1-2 pairs) have also been recorded in new areas or squares in Donegal, Leitrim and the Slieve Blooms (see above) reflecting either genuine range expansion and/or an artefact of increased survey coverage in these areas. A fourth confirmed new breeding pair was also observed in suitable habitat near the Westmeath and Longford border, and evidence of a possible breeding pair was also recorded in Roscommon.

3.4 Population estimates, population changes and habitat composition within SPAs

Further analysis was undertaken on the subset of 10km squares which include the SPAs (Figure 1). These squares held 57 confirmed pairs and 20 possible pairs (i.e. 57 – 77 pairs), a decrease from 2010 (69 – 94 pairs) and 2005 (85 – 93 pairs). This equates to a 17% decline since 2005. Since 2010, there has been a 17.4% decrease (-12 pairs) in the number of confirmed pairs and 20% decrease (-5 pairs) in the number of possible pairs in these SPA squares.

More explicit spatial mapping of the locations contained within the SPA boundaries shows that there were 51 – 69 confirmed and possible pairs contained wholly within the SPA network (Table 14). The population of hen harriers in the SPA network, based on 2005 survey data, was 82 – 94 pairs which has now declined to 51 – 69 pairs, representing an overall decline of 26.6% (Table 14).

Similar to 2010 some SPAs have increased since 2005 and others have declined, which ranges from an 80% decline recorded in the Mullaghanish to Musheramore Mountains SPA, to a 100% increase recorded in the Slievefelim to Silvermines Mountains SPA (Table 14). In terms of population losses, the most significant reduction within the SPA network since 2010 was recorded in the Slieve Aughty SPA with an overall reduction of nine breeding pairs since the 2010 survey.

Nationally within the SPA network there were 43.9% of total pairs (69 of 157 pairs; Table 14) are located within the SPA boundaries. Proximity analysis of buffers from the SPA network identified 4 – 5 pairs within 500m and 5 – 6 pairs (i.e. an additional 1-2 pairs) within 2km of the SPA boundaries although most of these (3) were located within Northern Ireland adjacent to Slieve Beagh.

Table 14. Numbers of confirmed and possible hen harrier territories within the boundaries of each of the six breeding hen harrier SPAs.

SPA	2005 Survey			2010 Survey			2015 Survey			Estimates of Change		
	Confirmed	Possible	Confirmed + Possible	Confirmed	Possible	Confirmed + Possible	Confirmed	Possible	Confirmed + Possible	Change (from 2005 - 2015)	Change (from 2010 - 2015)	% Change (from 2005 - 2015)
Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle (4161)	40	5	45	18	11	29	23	5	28	-17	**-1**	-37.7%
Mullaghanish to Musheramore Mountains (4162)	5	-	5	2	1	3	1	0	1	-4	**-2**	-80.0%
Slievefelim to Silvermines Mountains (4165)	4	1	5	6	1	7	4	6	10	5	**3**	100.0%
Slieve Bloom Mountains (4160)	5	3	8	9	0	9	12	1	13	5	**4**	62.5%
Slieve Aughty Mountains (4168)	24	3	27	15	8	23	8	6	14	-13	**-9**	-48.1%
Slieve Beagh (4167)	4	-	4	5	1	6	3	0	3	-1	**-3**	-25.0%
TOTAL	82	12	94	55	22	77	50	18	69	-25		-26.6%

3.5 Breeding outcomes and habitats utilised

There were 108 confirmed pairs and 49 possible pairs of hen harriers recorded during the 2015 survey. Only the confirmed pairs were investigated further for breeding outcome and habitat use since possible pairs had no observed evidence of likely nesting. The review of progression of breeding attempts in all confirmed pairs was supported by i) a small sample of nest visit information (mostly from Slieve Blooms and parts of the Stack's complex) and ii) behavioural observation of nest visitation, delivering prey to nests and remote counts of fledged young.

Nationally in 2015 there appeared to be a high rate of nest initiation recorded in confirmed pairs (i.e. where birds were recorded as visiting nests during behavioural observations) with 87% (n = 94) of confirmed pairs recorded to initiate a nest (i.e. at least recorded nest building and egg stage) with 5.5% (n = 6) not recorded to initiate a nest and 7.4% (n = 8) unknown whether a nest was initiated or not.

There were 66 pairs where it was indicated, from observations or nest visits, that hatching occurred which is 61.1% of confirmed territorial pairs. There were 21 pairs which were reported to fail at/before hatching stage (19.4% of confirmed pairs; 22.3% of pairs which nested). There were 13 nest records obtained during direct nest visits of the number of hatched young, which provides an average of 2.8 young (n = 13 broods; range 1-4). From the nests that successfully fledged young but where brood size was unknown it could be concluded that an additional 36 recorded nests hatched a minimum of a further 77 young (2.2 young per nest). There were 21 records (19.4%) where it was not known if hatching occurred or not.

The final breeding outcome was established at 97 of the 108 confirmed pairs with the remainder being unknown (n = 11). At least four of these 11 cases may have fledged young given the late stage of the final observations, however the final outcome was not confirmed and thus these have not been included as successful in this study but rather as outcome unknown. There were 48 (44.4%) successful pairs recorded to fledge a minimum of 102 young, which is 51.1% of pairs which nested (48 of 94), and brood sizes ranged from one to a maximum of five (2.1 young per successful pair; 0.94 young per confirmed breeding pair; see Table 16 & 18). This is similar to 2010 where 104 young fledged from 50 nests (2.1 young per successful pair). There were at least two leucistic chicks also recorded to fledge from a brood of four at one site in the Ballyhouras.

Known breeding failure of confirmed pairs was 45.4% (n = 49) and similar to 2010. If it is assumed that all possible pairs also failed then overall breeding failure rates in 2015 could be 98 of 157 pairs (62%) at all breeding territories which is greater than recorded in 2010 (51%). There were 11 records where the observer knew or suspected the cause of breeding failures at the nests. Ten of these were ascribed, by observers, to actual or suspected predation and two to disturbance related to turf-cutting which occurred close to the nest.

The most frequent habitat in which confirmed pairs were recorded was second rotation forest followed by heather, with fewer records in first rotation and scrub (Table 15). There were also small numbers of pairs located within heather in both first and second rotation forest and also scrub patches within heather moorland. Breeding success was highest at heather moorland nests (54%) and although failed forest appear higher (100%) sample sizes were very small.

Table 15. Nest habitat type and habitat specific breeding success of confirmed hen harrier breeding territories.

Habitat type	Number (n)	Percentage (%)	Breeding success (n)	Breeding success (%)
*First rotation**	6	5.5	2	33.3
*Second rotation***	64	59.3	26	40.4
Failed forest	1	0.9	1	100.0
Heather	28	25.9	15	53.6
*Scrub****	9	8.3	4	44.4
TOTAL	108	100%	48	-

Footnote: * includes one nest recorded as heather in first rotation; ** includes one nest recorded as heather in second rotation; *** includes two nests recorded as scrub in heather

Within SPAs there were 51 confirmed breeding pairs of which 25 (49%) were successful (Table 16). A minimum of 56 young fledged within SPAs during 2015 which represents an increase of 14 young when compared to 2010 (42 young fledged; Ruddock *et al*., 2012). Both Slieve Beagh SPA and Mullaghanish to Musheramore Mountains SPA contained only one successful breeding pair each.

Nesting habitats of confirmed breeding pairs within the SPAs (Table 17) were predominantly located within second rotation forest (38%) closely followed by heather moorland (37%), although nesting habitat varied between SPAs (Table 17) with a dominance of second rotation in the Stacks to West Limerick Hills complex and Slieve Aughties and a bias towards heather nesting in the Slieve Blooms, with broadly similar frequencies to nesting habitats recorded in 2010 (Ruddock *et al*., 2012).

Breeding parameters nationally were collated (Tables 18 & 19) and show that these varied between regions with more pairs outside the SPA network but with similar breeding success within and outside SPAs although the recorded number of young fledged per territorial pairs was lower outside SPAs (see Table 18). Nationally, most pairs were recorded in second rotation forest (59.3%) and heather moorland (25.9%).

Table 16. Breeding outcome and productivity within hen harrier SPAs showing numbers of records and percentage in parentheses.

SPA	Breeding outcome			Breeding output
	Successful n (%)	Failed n (%)	Unknown n (%)	Young fledged n
Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle	11 (47.8)	11 (47.8)	1 (4.3)	24
Mullaghanish to Musheramore Mountains	1 (100)	-	-	2
Slievefelim to Silvermines Mountains	2 (50)	2 (50)		3
Slieve Bloom Mountains	6 (50)	6 (50)		14
Slieve Aughty Mountains	4 (50)	4 (50)		9
Slieve Beagh	1 (33.3)	2 (66.7)		4
TOTAL	**25 (49)**	**25 (49)**	**1 (2)**	**56**

Table 17. Nest habitat type of confirmed territories within hen harrier SPAs and percentage (%) shown in parentheses

SPA	Habitat type				
	First rotation	Second rotation	Failed forest	Scrub	Heather
Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle	1 (4.3)	9 (39.1)	1 (4.3)	7 (30.4)	5 (21.7)
Mullaghanish to Musheramore Mountains*	-	-	-	1 (100)	-
Slievefelim to Silvermines Mountains	1 (25)	1 (25)	-	1 (25)	1 (25)
Slieve Bloom Mountains	-	1 (8.3)	-	-	11 (91.7)
Slieve Aughty Mountains	-	8 (100)	-	-	-
Slieve Beagh	-	1 (33.3)	-	-	2 (66.7)
TOTAL	**2 (3.9)**	**20 (38.5)**	**1 (2.0)**	**9 (17.3)**	**19 (37.3)**

* one nest in Mullaghanish to Mushermore recorded as scrub in heather but included in scrub category following definitions in Table 3.

Table 18. Breeding parameters of Irish hen harriers during 2015, showing number of sites (n) and percentages (%) in parentheses.

	Stacks	Mullaghanish Musheramore	Slieve Felim Silvermines	Slieve Blooms	Slieve Aughties	Slieve Beagh	Inside SPAs	Outside SPAs	Combined
Confirmed	23	1	4	12	8	3	51	57	108
Possible	5	0	6	1	6	0	18	31	49
Clutch initiation (%)	22 (95.6)	1 (100)	2 (50)	10 (83.3)	6 (75)	3 (100)	44 (86.3)	50 (87.7)	94 (87)
Clutch initiation unknown (%)	1 (4.3)	-	2 (50)	-	1 (12.5)	-	4 (8)	4 (6.9)	8 (0.1)
Hatching confirmed (%)	14 (60.8)	1 (100)	2 (50)	8 (66.7)	4 (50)	2 (66.7)	31 (60.8)	35 (61.4)	66 (61.1)
Failed to hatch (%)	3 (13.0)	-	-	4 (33.3)	4 (50)	1 (33.3)	12 (23.5)	9 (15.5)	21 (19.4)
Hatch unknown (%)	6 (26.1)	-	2 (50)	-	-	-	8 (16)	13 (22.4)	21 (19.4)
Total young fledged	24	2	3	14	9	4	56	46	102
Mean fledged young / confirmed pair	1.04	2.00	0.75	1.16	1.13	1.33	1.09	0.81	0.94
Mean fledged young / territorial pair (Confirmed + Possible)	0.86	2.00	0.30	1.08	0.64	1.33	0.81	0.52	0.65
Mean fledged young / successful pair	2.18	2.00	1.50	2.33	2.25	4.00	2.24	2.00	2.13
Successful (%)	11 (47.8)	1 (100)	2 (50)	6 (50)	4 (50)	1 (33.3)	25 (49)	23 (40.4)	48 (44.4)
Failed (%)	11 (47.8)	-	2 (50)	6 (50)	4 (50)	2 (66.7)	25 (49)	24 (42.1)	49 (45.4)
Unknown outcome (%)	1 (4.3)	-	-	-	-	-	1 (2)	10 (17.5)	11 (10.2)

Table 19. Breeding parameters of Irish hen harriers during 2015, separated by habitat type, showing number of sites (n) and percentage (%) in parentheses.

	Stacks	Mullaghanish Musheramore	Slieve Felim Silvermines	Slieve Blooms	Slieve Aughties	Slieve Beagh	Inside SPAs	Outside SPAs	Combined
First rotation (1F)	1 (4.3)	-	1 (25)	-	-	-	2 (3.9)	4 (7)	6 (5.5)
Second rotation (2F)	9 (39.1)	-	1 (25)	1 (8.3)	8 (100)	1 (33.3)	20 (39.2)	44 (77.2)	64 (59.3)
Failed forest	1 (4.3)	-	-	-	-	-	1 (2)	-	1 (0.9)
Scrub (S)	7 (30.4)	1 (100)	1 (25)	-	-	-	9 (17.6)	-	9 (8.3)
Heather moorland (H)	5 (21.7)	-	1 (25)	11 (91.7)	-	2 (66.7)	19 (37.3)	9 (15.8)	28 (25.9)
Afforested habitats (incl 1F, 2F, failed forest)	11 (47.8)	-	2 (50)	1 (8.3)	8 (100)	1 (33.3)	23 (45.1)	47 (82.5)	71 (65.7)

3.6 Pressures

Nationally and regionally there were extensive and widespread efforts to record pressures within areas containing hen harriers and/or areas with suitable hen harrier habitat. Field surveyors provided large numbers of records of pressures within 500m (n = 4,145) and 2km (n = 3,947) of these areas. Most frequent records numerically and proportionally (Table 20; see Table 5 for list of codes) within 500m was D1 (paths, tracks, cycling tracks; includes non-paved forest roads; n = 337; 9.1%) and B2 (forest and plantation management & use; n = 375; 9.1%) and within 2km was again B2 (n = 391; 9.9%) and D1 (n = 292; 7.4%).

Table 20. The cumulative numbers of each pressure code recorded within 500m and 2km of the centre of the hen harrier territory, nest site and/or suitable breeding habitats.

Pressure code	Number of pressures within 500m	Percentage of total pressure records within 500m	Number of pressures within 2km	Percentage of total pressure records within 2km
A1	0	0.0	0	0.0
A2	62	1.5	234	5.9
A3	6	0.1	8	0.2
A4	10	0.2	9	0.2
A5	76	1.8	109	2.8
A6	351	8.5	164	4.2
A7	52	1.2	49	1.2
A8	5	0.1	16	0.4
A9	60	1.5	56	1.4
B1	89	2.2	96	2.4
B2	375	9.1	391	9.9
B3	89	2.2	91	2.3
B4	42	1.0	160	4.1
B5	7	0.2	5	0.1
B6	2	0.1	0	0.0
B7	10	0.2	0	0.0
C1	57	1.4	59	1.5
C2	141	3.4	131	3.3
C3	101	2.4	149	3.8
D1	377	9.1	292	7.4
D2	219	5.3	226	5.7
D3	117	2.8	143	3.6
D4	1	0.1	9	0.2
D5	20	0.5	14	0.4
E1	4	0.1	14	0.4
E2	71	1.7	78	2.0
F1	34	0.8	34	0.9
F2	0	0.0	0	0.0
G1	91	2.2	61	1.6
G2	91	2.2	55	1.4
G3	93	2.2	56	1.4
G4	70	1.7	60	1.5
G5	83	2.0	105	2.7
G6	13	0.3	9	0.2
G7	16	0.4	20	0.5
H1	2	0.1	1	0.1
J1	6	0.1	11	0.3
J2	66	1.6	67	1.7

Pressure code	Number of pressures within 500m	Percentage of total pressure records within 500m	Number of pressures within 2km	Percentage of total pressure records within 2km
J3	140	3.4	190	4.8
J4	8	0.2	9	0.2
J5	332	8.0	188	4.7
J6	13	0.3	13	0.3
J7	60	1.5	75	1.9
K1	69	1.7	56	1.4
K2	346	8.4	211	5.4
X	218	5.3	183	4.6
O	50	1.2	40	1.0
	4,145	100%	3,947	100%

Recorded pressures varied regionally (Table 21; Figures 14 & 15) with most frequent records obtained from the Boggeragh – Derrynasaggart Mountains; Stack's, Glanaruddery, Knockanefune, Mullaghareirk Mountains complex; Ballyhouras Mountains and Slieve Aughty Mountains respectively.

Other pressures i.e. which were not under a specific pressure code (Table 5) specifically recorded by observers within 500m and 2km of survey areas included forest maturation; scrub, bracken and invasive conifer encroachment on moorland; mining / quarrying and trampling by livestock. Inter-specific interactions were recorded with other avian species (code K1) including buzzard, raven and hooded crow, and mammalian species (code K2) which included pine marten and fox.

Within the SPA squares there were 1,443 and 1,553 pressures recorded in the 500m and 2km zones respectively, which varied between the SPAs (Appendix 4 – 9 & 10; see also Figures 14 & 15). Within 500m of survey areas across all SPAs the most frequently recorded pressures were D1 (paths, tracks, cycling tracks (included non-paved forest roads); n = 166), B2 (forest and plantation management & use; n = 147) and X (no pressures; n = 112).

Within 2km of survey areas in SPAs, the most frequently recorded pressures were B2 (forest and plantation management & use; n = 171); D1 (paths, tracks, cycling tracks (included non-paved forest roads); n = 114); J3 (uncontrolled burning; n = 112); C3 (wind energy production; n = 105) and B4 (forest clearance (clear-cutting, removal of all trees); n = 103), although these again varied between regions (Appendix 10).

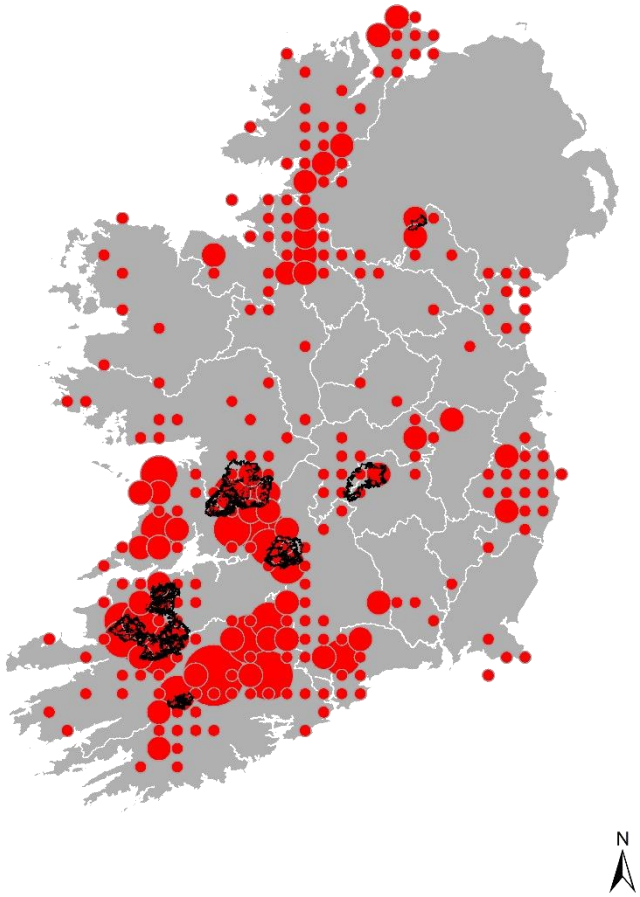
A summary document for each breeding hen harrier SPA including information on population trends, habitat composition, pressures, habitat suitability was collated and can be found at Appendices 4 – 9.

Table 21. Regional breakdown of cumulative pressures to show total number of pressure records (Pressure Index 1) and standardised (Pressure Index 2 = total number of pressures / total number of visits to square) within 500m and 2km of hen harrier territories and/or suitable hen harrier breeding habitats.

Regional areas	Pressure Index 1 (500m)	Pressure Index 2 (500m)	Pressure Index 1 (2km)	Pressure Index 2 (2km)
Ballyhouras	358	10.7	336	9.7
Blue Stack Mountains, Pettigo Plateau, South Donegal	84	9.0	84	9.8
Boggeragh, Derrynasaggart Mountains	970	30.6	545	29.7
Castlecomer, Blackstairs, Kilkenny	0	0.00	0	0.0
Curlew Mountains	0	0.00	0	0.0
Devilsbit, Slievefelim, Silvermines, King Hill	130	7.0	77	4.6
East Cork, Waterford	3	0.7	2	0.4
Galtys	46	6.0	69	11.4
Inishowen	51	2.4	50	2.8
Kildare	25	3.1	24	3.0
Knockmealdown, Kilworth, Comeraghs	185	14.2	227	17.3
Leitrim, Slieve Rushen	145	16.1	130	13.4
Longford	0	0.0	0	0.0
Nagles	181	8.8	279	13.2
North & West Clare	274	14.7	244	12.9
North-west	7	1.4	4	0.7
Ox Mountains	17	1.9	17	1.9
Roscommon	0	0.0	0	0.0
Slieve Aughty Mountains	352	9.8	466	11.3
Slieve Beagh	46	1.9	52	2.9
Slieve Bernagh-Keeper Hill	208	13.7	302	20.6
Slieve Blooms	50	0.9	29	0.5
South of Roscrea	10	3.3	7	2.3
Stack's, Glanaruddery, Knockanefune, Mullaghareirk Mountains	672	37.3	652	38.6
West Cork	31	3.3	38	5.8
West Kerry	0	0.0	0	0.0
Wexford	0	0.0	0	0.0
Wicklow Mountains	112	13.0	143	19.8
Other areas	185	41.3	167	40.3
TOTAL	4145	251.4	3947	273.2

Figure 14. Index of pressures recorded within 500m of hen harrier territories and/or suitable habitat during field observations. SPA boundary outlines are shown and the size of the circles indicates the frequency recorded pressure (as per Table 5). Pressure Index 1 (left) and Pressure Index 2 (right) are shown.

(i) Pressure Index 1 – 500m



(ii) Pressure Index 2 – 500m

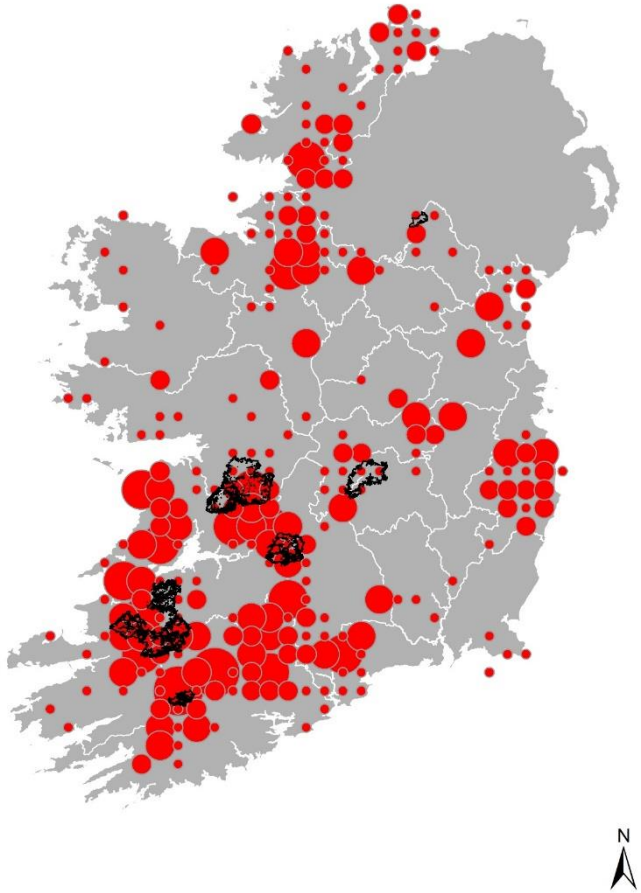
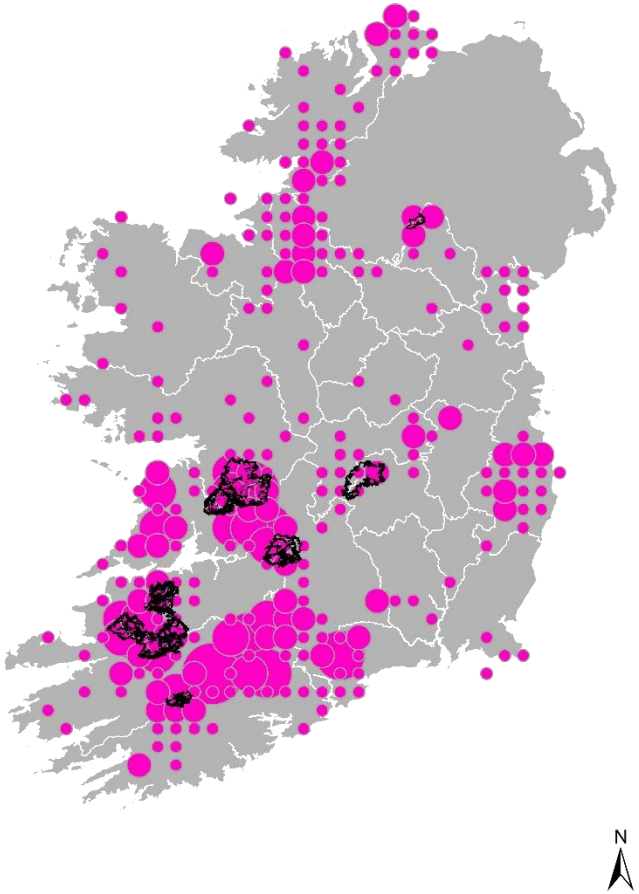
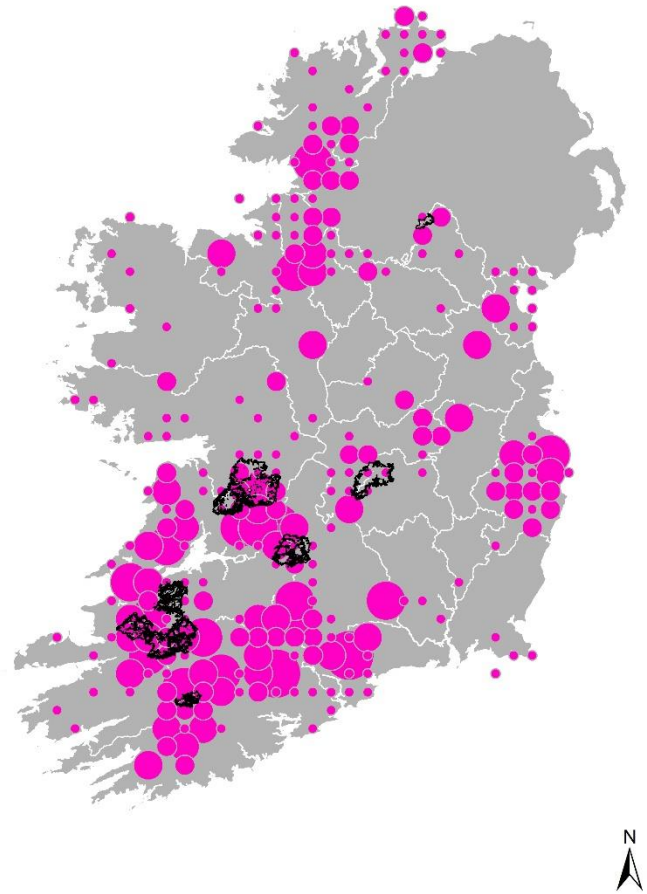


Figure 15. Index of pressures recorded within 2km of hen harrier territories and/or suitable habitat during field observations. SPA boundary outlines are shown and the size of the circles indicates the frequency recorded pressure (as per Table 5). Pressure Index 1 (left) and Pressure Index 2 (right) are shown.

(i) Pressure Index 1 – 2km



(ii) Pressure Index 2 – 2km



3.7 Other research

There were 23 other species recorded during ancillary recording (Table 22) which were mapped by 10km across Ireland (Appendix 12). Most frequently recorded (after hen harrier), was the kestrel, buzzard and sparrowhawk. Curlew records were also submitted by field observers to the 2015 National Curlew Survey (B. O'Donoghue & A. Donaghy, personal communication) to inform the results of that study. There were several records of species received, predominantly more common and widespread species, which were not on the recording list and therefore will have been wholly under-recorded, but nevertheless any records submitted for all species are summarised here (Table 22).

Table 22. The records of other bird species recorded during hen harrier surveys showing number of detections and number of recorded squares.

BTO Code	Common name	Latin name	Number of records	Number of 10km squares
BZ	Buzzard	*Buteo buteo*	112	87
CK	Cuckoo	*Cuculus canorus*	5	5
CU	Curlew	*Numenius arquata*	25	16
EA	Golden eagle	*Aquila crysaetos*	3	3
GH	Grasshopper warbler	*Locustella naevia*	1	1
GP	Golden plover	*Pluvialis apricaria*	11	9
H.	Heron	*Ardea cinerea*	1	1
HC	Hooded crow	*Covus corone cornix*	36	14
HH	Hen harrier	*Circus cyaneus*	2222	162
HY	Hobby	*Falco subbuteo*	2	2
K.	Kestrel	*Falco tinnunculus*	334	102
KT	Red kite	*Milvus milvus*	15	7
L.	Lapwing	*Vanellus vanellus*	5	3
MA	Mallard	*Anas platyrhynchos*	1	1
ML	Merlin	*Falco columbarius*	29	18
MR	Marsh harrier	*Circus aeroginosus*	2	2
PE	Peregrine	*Falco peregrinus*	23	19
RB	Reed bunting	*Emberiza schoeniculus*	1	1
RG	Red grouse	*Lagopus lagopus*	23	20
RK	Redshank	*Tringa totanus*	1	1
RN	Raven	*Corvus corax*	25	15
SH	Sparrowhawk	*Accipiter nisus*	83	54
SL	Swallow	*Hirundo rustica*	1	1
SN	Snipe	*Gallinago gallinago*	23	17

A wing tagged hen harrier was recorded in the Slieve Aughties which was previously tagged as a chick at the nest in the Slieve Blooms. Whilst some nests were visited under licence for tagging and collection of prey remains in 2015 the results of these studies are not reported here. Extensive licensed research was undertaken in the Slieve Blooms during 2015 which involved the installation of remote nest cameras to examine prey and provisioning rates and behaviour (Figure 16), which confirmed the direct cause of one nest failure as predation by pine marten (Figure 17).

Figure 16. Female hen harrier feeding a nestling in the Slieve Bloom Mountains. © J. Monaghan

Figure 17. Pine marten (foreground) recorded within hen harrier nest predating young in the Slieve Bloom Mountains © J. Monaghan

4.0 Discussion

4.1 Survey implementation, coverage and data submission

There was a 138% increase in the numbers of people that participated in fieldwork for this survey compared to the 2010 survey (Ruddock *et al.*, 2012). This was undoubtedly aided by the partnership between co-ordinating organisations (GET, IRSG & BWI) and NPWS in communicating with a vast network of potential observers. The implementation of the survey was further improved from the 2010 survey model by the clear division of regional zones (Figure 1) amongst project co-coordinators, and in the authors' views, considerably increased efficacy of survey deployment, fieldwork, follow-up, communication and collation of data with the fieldworker network. This process also allowed vetting of surveyors' ability prior to the survey effort (via workshops and training) and on-going verification of data accuracy and square coverage as the survey progressed. This division did however necessitate continued and sustained communication between regional co-ordinators to avoid duplication of effort particularly at zone boundaries. There was potential for duplication of some records since some observers' submitted information both online and to regional co-ordinators. This required some cleaning and manipulation of the databases to remove duplicated records and survey effort and ensure data integrity.

The training workshops, field based training and team surveys in 2015 have greatly increased the volunteer network field skills and thus the quality of the survey data which will benefit future surveys (Dickinson *et al.*, 2010; Lohmus, 2011). It is, however, important to encourage these volunteer resources in the intervening years between national surveys to ensure continued development of the volunteer network. The value in training and interaction with regional fieldworkers, for hen harrier surveys, is evidenced further by the considerably increased participation of volunteers since initial training workshops in 2010.

There was an increased number of squares identified for survey during the initial data review (n = 308) compared to 25.3% fewer squares in 2010 (n = 230). Following field review of these squares and ground-truthing some were identified as not currently suitable (n = 42) and others classified as marginal suitability (n = 25). It was noted that the addition of the Bird Atlas data (Balmer *et al.*, 2013) appears to have identified some coastal and lowland sites that may have been recorded as late winter/early spring or late summer/autumn records in that study. However, ground-truthing during this survey revealed habitats that are more suited to wintering roost locations. Ahead of any future surveys it will remain necessary to review the suitability of the squares including by incorporating the review of square suitability as carried out in 2015.

The increased number of fieldworkers facilitated a high level of coverage nationally with 251 squares (81.5%) of all identified squares (n = 308) surveyed. Along with an additional coverage of 19 unallocated squares, the numbers of surveyed squares increased by 81.2% from 2010 (149 to 270 squares). Phenomenally, there was 100% coverage of priority ('green') squares covered during 2015 which represents an increase of 85.4% from 2010 (Ruddock *et al*. 2012). All other squares (priority groups 'yellow'; 'orange'; and 'red'; Figure 1) also received higher proportional coverage in 2015 (82%; 73% & 67% respectively) compared to 2010 (52%; 51%; 34%). Similar to 2010 the 'red' priority squares were covered less frequently than other priority groups. Although it is recognised that not all survey visits were undertaken, it is important that volunteer coverage is practicable and not overly onerous for observers. Therefore for future surveys it would be useful to ensure that squares allocated for coverage contain suitable habitat and increase visitation rates to individual squares. Whilst there was good coverage of the randomly selected squares (n = 104 of 125) in order to provide a statistical estimation of population size and confidence limits (e.g. Hoodless *et al*., 2009), coverage of these was incomplete. Further review and analysis of this information is necessary to provide the random square derived estimate for Ireland.

The submission of data was improved and much expedited from the previous survey in 2010, with all data received by 22nd October compared to the 18th November in 2010. Similar to 2010, the majority of the data was received beyond the 31st August submission deadline. However on-going data entry and the provision of an online recording system facilitated expedited submissions throughout the survey period. All data was cleaned and clarified by 27th October 2015 (five days) compared to 11th March 2011 (114 days). This was facilitated by on-going data entry, manipulation and checking by regional co-ordinators throughout the survey period. Throughout, and following, data submission there was a requirement for regional co-ordinators to liaise with observers directly to obtain clarification where necessary. Some key information to derive breeding status was absent from some records including details of habitats, behaviours and grid references, particularly where only summary data was received, which required clarification to ensure data could be mapped and was accurately validated and reported.

The implementation of online data entry followed the recommendations of Ruddock *et al*., (2012) to support standardisation of data (see also Hackler & Saxton, 2007; Blatz & Duff, 2014) and to minimise data errors or biases (Tyre *et al*., 2003; Royle, 2008). This system proved useful and helped standardise much of the initial data received. However a larger proportion of hard-copy data or bespoke databases were received that still required digitisation and standardisation by project co-ordinators. Some observers reported that the utility of the online system was difficult and it is recommended that some further improvements are undertaken in the future to this recording method in further consultation with observers (Chen *et al*., 2010) and further increase efficacy of data collation and

increase data quality. The public web-based sighting form allowed collation of more than 100 casual records which were verified (typically by photographs) by project co-ordinators and also facilitated considerable engagement with the wider public in submitting sightings to the project. The incidence of submission of these sightings was noticeably linked with social media interactions by the co-ordinating organisations and further highlight the usefulness of these platforms for engaging with a wider audience and obtaining useful data for scientific and monitoring projects (Van Noorden, 2014).

There was evidence of variation in spatial locations for some records where multiple observers were operating independently although these were readily detectable and were clarified during data validation where necessary. For a small number of squares no data was received. These were excluded from further analysis. Subsequently it has been confirmed that no extra confirmed or possible pairs were recorded in these non-submitted data. Some of these non-submitted records included some random squares, which further compromised the usage of the random squares to provide a statistical population estimate and requires further analysis and these non-submitted data to derive such an estimate.

Similar to the 2010 survey, the support and efforts of the vast number of volunteer fieldworkers, raptor researchers, governmental staff, non-governmental staff and commercial surveyors was excellent and commendable in delivering the data to inform a robust population spatial and numerical assessment.

4.2 Survey effort and observations

Given the large increase in observer participation a concomitant increase in survey effort was achieved. A 55% increase in the number of records received and a 62% increase in the number of vantage point and casual observations was recorded. The hours of survey effort was increased by 77% from 2010 (Ruddock *et al.*, 2012) and by 260% when compared to the survey effort achieved in 2005 (Barton *et al.*, 2006). Some data were received in summary format only and thus the survey effort hours obtained represents a minimum effort with other effort known but not reported or submitted. Again, the high quality and quantity of effort by field observers assured robust data platform for population analyses.

The visit schedule as defined in the survey methods (Section 2.4) is important to minimise any biases in the data recorded. It is important to be mindful that it may be possible to under-estimate the breeding density or classification of breeding attempts if key visits are missed or duration of visits are not adequate. Overall effort was high nationally (>7000 hours) but effort varied seasonally and effort varied between squares from five minutes to more than 248 hours with an average of around 26 hours per square. There was thus disproportionate coverage in some squares, although it is recognised that

this can be heavily biased by the quantity of suitable habitat and hen harrier activity in individual squares and individual observer effort.

Similar to 2010 (Ruddock *et al*., 2012) there were incomplete visit schedules undertaken. However, these were proportionally increased from both previous surveys in the early season which is important in identifying breeding locations. During Visit 1 (March to mid-April) surveys were completed at 62% of squares in 2015 compared to 59% in 2010 and 60% in 2005. With regard to Visit 2 (mid-April to mid-May), these were similar in 2015 (81%) and 2010 (also 81%) but increased from 2005 (76%). Final visits were higher in 2015 (57%) than 2010 (54%) but less than 2005 (67%) which may affect the establishment of final breeding outcomes, although the records received for known breeding outcomes were actually higher in 2015 than previous surveys indicating that this was not biased. An increased effort in Visit 3 (mid-May – mid-June) between 2010 (50%) and 2015 (57%) ensured a high level of coverage and establishment of breeding outcome compared to previous surveys.

Importantly, the risks identified in Ruddock *et al*., (2012) regarding the reduced likelihood of classifying a breeding attempt as either confirmed or possible if visitation rates, particularly early visits, were lower was mitigated during 2015 with increased visitation rates which were greater than 75% throughout. The squares which contained confirmed breeding pairs were visited 79% (visit 1); 100% (visit 2); 84% (visit 3) and 95% (visit 4) with squares containing possible pairs visited 82% (visit 1); 100% (visit 2); 77% (visit 3) and 86% (visit 4). First visits in 2010 (72%) and 2005 (72%) were lower for confirmed pairs and possible pairs (66% & 38% respectively) and thus reduces the risk that other confirmed or possible pairs were not correctly identified or classified in 2015.

This, along with the increased survey effort and coverage, provides increased confidence in the population estimates in this study. It would be desirable in future surveys to further increase the frequency of first visits to squares, and training workshops in January or February in subsequent surveys may assist in deployment of earlier visits nationally by the end of March and early April.

Behavioural information recorded were comparable to the findings of the 2010 survey with the most frequent of all observations and particularly foraging observation recorded in open habitats (c 51 - 53%; see Table 9 for definition of open habitats) compared to afforested habitats (c40 - 43%) although these had not significantly changed between survey years. All observations in the open habitats had marginally increased (c 45% to 50%) and the latter had marginally declined (c 49% to 43%) although differences between years were not significantly different. There was an apparent change in the frequency of detection of foraging birds within first rotation forest (c 12% to 8%) and thicket stage forest (c 9% to 12%). Whilst this had not significantly changed between survey years it may be useful to continue to monitor these metrics in future to understand any significant habitat usage changes. The recorded change may indicate a shift in usage of these habitats for foraging by hen harriers based

on the age profile of forests, and also may reflect the recent lack of afforestation within the SPA network (i.e. lesser availability of new forest) in parts of the hen harrier range (see NPWS, 2015).

Even though foraging observations within the linear features category was not recorded frequently the 2015 data does, however, concur with other studies (Schipper, 1977; Thompson-Hanson, 1984; Martin, 1987; Clarke & Watson, 1990; Redpath, 1992; Madders, 1997; 2000; 2003; O'Donoghue, 2010; 2012; Irwin *et al*., 2012) that these landscape features are useful and may be important for connectivity for hen harrier foraging areas. Notably firebreaks and power-line corridors (latter particularly recorded in the Slieve Aughties) may provide some connectivity for foraging birds in heavily afforested or similarly homogeneous habitat areas. Whilst some of these features may have an associated collision risk or displacement risk (Pearce-Higgins *et al*., 2009) the creation of corridors may provide a useful method to increase habitat connectivity in hen harrier breeding areas. Perhaps this concept has management implications in providing corridors for movement and optimisation of breeding and foraging areas for hen harriers which is a recognised useful wildlife management tool (Lindenmayer & Nix, 1993; Rosenberg *et al.,* 1997; Lindenmayer *et al.*, 2002; Bond, 2003; Jones *et al*., 2009). Insufficient records were obtained to statistically examine the usage patterns of such linear features within or between areas but this warrants further investigation and management consideration in the future.

4.3 National and regional population estimates, population change and breeding density

The breeding population of hen harriers in Ireland has declined nationally since 2010 with an 8.4% decline in the maximum population or an 11.7% decline based on the mid-point values. The maximum population recorded in 2015 is slightly higher than 2005 showing a 2.6% increase (153 versus 157) whilst comparison of the mid-point estimate shows a 6.7% decline. Since 1998 – 2000 surveys (Norriss *et al*., 2002) the maximum numbers have apparently increased by 21.7% whilst mid-point values show a lesser increase of 14.7%.

The use of the mid-point values generally shows an increase from the first national survey which may be explained by increasing survey effort over subsequent surveys. A comparison of the mid-point value between the second and third national surveys shows a steady decline. It appears also that the recorded rate of decline has almost doubled (6.7% to 11.7%) in the most recent five years in spite of increased survey effort. Based on the same continued rate of decline found in 2015 (11.7% every five years or 2.34% annually) means there could be fewer than 100 pairs of hen harrier in Ireland within 25 years if this rate of decline is not halted and reversed. This prediction assumes that the rate of decline does not double again as it appears to have done over the last 10 years.

Whilst the national population appeared to increase between 2005 and 2010 (Ruddock *et al*., 2012) this may have been largely due to the increasing effort and despite a further increase in survey effort between 2010 and 2015 a national population decline is now recorded. This further supports the validity of a genuine population decline recorded in 2015. In addition to this, it is possible to further reduce risks of biases in estimation of population size by use of the sub-set analyses between surveys to ensure comparability.

Most robustly, the subset of 139 squares surveyed in both 2010 and 2015 shows a decline of 16.4% of confirmed and possible pairs and thus the actual rates of decline may actually be higher than examining national estimates which may have been 'artificially increased' by the increasing survey effort between surveys over a greater number of squares. Whilst some squares appear to be exhibiting acute declines (with losses of up to six pairs per square) some declines may be mitigated to some extent by concomitant increases recorded in neighbouring squares in some regions. However, if this redistribution was equivalent it would seem logical that there would be a stable population within the subset of squares. Thus evidence supports the hypothesis that numbers are not largely biased by increasing survey effort (by hours input and increasing survey areas) nationally since there is a declining population even within this subset of squares.

The further subset of 110 squares surveyed in 2015, 2010 and 2005 also shows the maximum population in these squares has declined by 16.7% and 9.7% respectively compared to 2015 population metrics. Further, to control for biases in survey effort, comparison of a smaller subset of 78 squares which were covered in all national surveys (1998 – 2000; 2005; 2010 & 2015) revealed an overall decline of approximately one third in the maximum population during this 15 year timeframe. Although this varied between surveys with a decrease recorded from 1998 – 2000 until 2005 (18%) followed by an increase from 2005 to 2010 (4%) and then a further decline from 2010 to 2015 (22%). This indicates that increased survey effort between 2005 and 2010 may have recorded a genuine population increase but also that in the short-term (5 years) and long-term (>15 years) declines now recorded cannot be explained by differences in survey effort alone. In fact, the current national population declines may actually be greater than estimated due to the continually increasing survey effort between surveys.

Breeding range has changed between surveys with an apparent increase in the total number of squares in which hen harriers are recorded in Ireland including between 2010 and 2015, although these are largely a result of an increase in the number of possible breeding pairs. The number of squares in which confirmed breeding pairs are recorded has remained relatively stable between 2005, 2010 and 2015. In 2015 there was a more than a 200% increase in the number of squares with possible breeding pairs. However, while it is likely that this is, at least in part, an artefact of increased survey effort there are also some apparent changes in spatial distribution where decreases in some squares may be at least partly reflected or absorbed in neighbouring squares (see Figures 7 & 10). It is also

conceivable this increase in possible breeding pairs and range could indicate a shifting range from formerly suitable and/or stronghold areas to other areas which may be less suitable and less likely to support a breeding pair.

It is therefore difficult to establish if this reflects a genuine range expansion or is a direct result of increased survey effort and increasing number of squares surveyed between national surveys. Nevertheless, these increases appear to occur mainly beyond the subset of squares analysed since the nett gains do not result in a stable population and a nett loss is instead recorded. This occurs despite increasing survey effort and increasing survey areas, it therefore remains that a national population decline is recorded although the breeding range appears increased. This may mean that whilst some pairs could be redistributed and/or be discovered via increasing survey effort generally, there appears to be an actual reduction in density within all surveyed squares. This includes the subset squares covered during each of the preceding surveys as otherwise a stable national population would be recorded.

There have been further changes in some regional populations. Some of which are similar to the trends recorded in 2010 such as in Donegal the Blue Stacks, Pettigo and South Donegal areas where numbers are recorded to increase since all previous surveys (Figures 9 & 10). However it is noted that a small number of losses in squares were also recorded and thus movements at a local scale may account for at least some of the recorded increases in this area (i.e. pairs moving locally in response to changes in e.g. habitat or suitability). Undoubtedly increased survey effort in this area in 2010 and again in 2015 has located some genuine increases as well as previously undocumented breeding locations.

Slieve Rushen sites have actually declined since 2010 and much of the plantation in that area is currently considered unsuitable for nesting by observers due to forest maturation since the previous survey. Some apparent increases and/or movements or redistribution of pairs were also noted in Leitrim, but these largely remained within previously identified breeding squares. There may have been some shift westward immediately adjacent to Slieve Rushen (Figures 7 & 10) and further afield to the Leitrim complex (evident in Figures 7 & 10) perhaps in response to some of the favourable habitat management occurring in that area (e.g. at Boleybrack Mountain; J. Carslake, personal communication; L. O'Toole, personal observation). While these areas are largely contiguous, the distances involved may be quite large for such displacement to occur (20 – 40km) and it is not possible to prove this redistribution concept in the absence of individually marked birds.

The Slieve Aughties did show a decrease in 2015 which perhaps may be partly due to redistribution of breeding pairs to the south of the site. However, observers noted that forest maturation is likely to have reduced the availability of suitable habitat since previous surveys in this area. Some increases were recorded in the squares south of the Slieve Aughties towards the Slievefelims – Devilsbit -

Silvermines complex (which is evident in Figures 7 & 10). It is conceivable that some of the breeding pairs may have relocated (10-20km south) from former traditional nesting areas within the Slieve Aughties, which may have occurred in response to site specific drivers within that range.

Slieve Bernagh – Keeper Hill has increased since all previous surveys (by up to 250%) and this area appears to have increased particularly since 2010 to a maximum of seven breeding pairs although this may, in part, be due to increased survey effort. However, this is similar to the recorded increases in the Slievefelim – Devilsbit – Silvermines area noted above (and evident on Figures 7 & 10) to the south of the Slieve Aughties and it seems likely that these areas have, at least in part, increased as the Slieve Aughties have declined. These increases therefore may be due to redistribution of breeding pairs from the Slieve Aughties, although survey effort has also increased in all these areas in the recent surveys (Ruddock *et al*., 2012; this study). The increases however do not match the decreases regionally or nationally and therefore there remains a nett decline despite some apparent redistribution of breeding pairs.

Short-term declines since 2010 are recorded in the Nagles, Galtys and north – west Clare but these areas are in fact recorded as increased from the earlier 1998 – 2000 surveys although survey effort has increased over time. Some increases have been observed at the Knockmealdowns – Kilworth – Comeraghs complex. However, survey coverage was considered more complete in the Knockmealdowns in 2015 where the majority of the pairs are located in this complex, with just single pairs in the Kilworth and Comeragh Mountains respectively. Three of the five confirmed pairs in the Knockmealdowns are in heather moorland which is perhaps more extensive and of higher quality here than elsewhere in Munster. Use of heather moorland sites is likely to be more stable over time than afforested sites. One on these pairs traditionally nests on moorland managed for its red grouse population by the local gun club (W. Shortall, personal communication).

Much larger decreases over the long-term have been recorded in the Stack's, Glanarudderies, Knockanefune, Mullaghareirks, North of Abbeyfeale complex although the numbers appears stable since 2010 (see Ruddock *et al*., 2012) although annual monitoring in this area has apparently shown a decline from 2010 to 2014 with an increase in 2015 (B. O'Donoghue, personal communication). It is important to understand management over the last five years to see if this apparent stabilisation is occurring between survey years due to site specific factors or management and further consideration also whether this could be a result of immigration from elsewhere.

At Slieve Beagh only three pairs were confirmed in Monaghan and other traditional pairs from Monaghan appear to have shifted westward into adjacent counties Tyrone and Fermanagh since the previous survey. Numbers in the wider area appear stable (including Tyrone & Fermanagh portions) holding six confirmed and 2-3 possible pairs. However, a definite spatial shift away from the traditional Monaghan moorland core has occurred and the new 'core' breeding area now appears to

be in afforested areas north and west of traditional breeding areas and mostly in the Northern Ireland SPA. This may explain the recent increase in population reported in site condition assessments for the Slieve Beagh – Mullaghfad – Lisnaskea SPA (Northern Ireland) (Enlander & Wright, 2015).

The Slieve Blooms are noted to have increased since all previous surveys and despite much forest cover in the area, only one nest was recorded in young plantation here, with the majority of pairs nesting in heather moorland. The management and high quality annual monitoring in this region have ensured consistent annual monitoring outputs which concurs that the population in this area is stable between years also (J. Monaghan & C. Tweney, personal communication; Monaghan, 2012; 2013; 2014). The Slieve Blooms Nature Reserve is specifically managed to ensure conservation of the blanket bog ecosystem including removal of invasive alien conifers, ditch blocking, access control and hydrological monitoring (www.npws.ie/nature-reserves/slieve-bloom-mountains). This area could be considered high quality moorland habitat which is relatively stable between years and this is also a likely reason, that despite high forest cover the local hen harrier population here remains stable.

The Ballyhouras appears to have marginally declined since 2010 (20%; Ruddock *et al.*, 2012; this study) and has decreased more extensively since 2005 (Barton *et al.*, 2006) by approximately 37% and observers report a relatively high level of disturbance related pressures (see Section 4.6) in this area both during the survey and in recent years. This area has received a considerable increase in visitor numbers due to its promotion as an area for outdoor activities (see www.visitballyhoura.com). There is also widespread use of forest tracks and more critically off-road use of open heather moorland and blanket bog within the Ballyhouras SAC, by all-terrain vehicles and scrambler bikes especially has resulted in damage to this limited habitat within the Ballyhouras (A. Mee, personal observation). Several such vehicles were noted by surveyors in the east side of the Ballyhouras where access from nearby roads is relatively easy and was noted by surveyors to have been exacerbated elsewhere in the range since the mountain bike trails were established. This increase in activity may be an additional pressure to the hen harrier population in the Ballyhouras. Whether related or not to recreational use, the only traditionally heather nesting pair of harriers in the main Ballyhoura range did not attempt to nest at this site in 2015. Heavy use of forest tracks by off-road vehicles is also reported to be commonplace in the Nagles (T. Nagle, personal observation).

In all regional areas the results of this study do not allow conclusions to be drawn on the causative factors behind increases and/or decreases and there are complications when analysing results at five year intervals since other annual increases or decreases may be occurring (see also Ruddock *et al.*, 2012; NPWS, 2015). It must be borne in mind that some apparent increases may also be accounted for by increased survey effort (see Irwin *et al.*, 2008; Ruddock *et al.*, 2012) both regionally and nationally. The recording of pressures (Section 4.6) aimed to facilitate some insights into occurrence of actions, management or activities and/or suitability relevant to breeding hen harriers in the survey areas but

any future analysis of causative factors should aim to establish causal links on a regional basis to implement targeted management.

4.4 Population estimates, population changes and habitat composition within SPAs

There were declines recorded in the 10km squares which contain the SPAs revealing an 18.1% decline in the maximum population size since 2010 and has declined by 17.1% since 2005. There are currently 57 – 77 breeding pairs recorded within these squares, which is approximately 49% of the 2015 national population. Within the SPA boundaries a smaller number of pairs occur (51 – 69 pairs) since boundaries do not encompass the whole 10km squares, which equates to 43.9% of the national population. These total numbers have declined by 10.4% since the previous survey (Ruddock *et al.*, 2010) and 26.6% since the 2005 survey (Barton *et al.*, 2006). It appears the rate of decline has slowed since 2010 (18% to 10%) although overall the SPA network population has still declined by more than a quarter within 10 years.

Similar to 2010, some of the SPAs recorded an increase – specifically the Slieve Blooms and the Slievefelims to Silvermines Mountains whilst all other sites recorded declines. The latter complex is noted in earlier regional analysis to potentially have increased as a result of movements from the Slieve Aughty Mountains although this cannot be proven.

The breeding range of the Slieve Blooms population was recorded to expand to the north in 2015 with an additional breeding pair recorded in a new square since the previous survey, which indicates a genuine increase in both range and population size. The majority of this population nest within heather moorland despite extensive forest cover (63%) based on Moran & Wilson-Parr (2015) in this SPA compared to other SPAs (Appendices 4 – 9). This indicates that forest cover may not be a key driver of this population. However, this area is exceptional in the habitat and ecological management (see Monaghan, 2012; 2013; 2014) that has been carried out, which is has resulted in a high availability of alternative, high quality moorland. This may currently mitigate for the higher forest coverage, although this dynamic ultimately may yet also be affected by the ageing forest profile, reducing foraging habitat further. This is expected over the next 10 years (Appendices 4 – 9) and it is estimated that the extent of useable forest for nesting and foraging purposes is declining year on year (NPWS, 2015).

The Mullaghanish to Musheramore Mountain SPA population is now perilously at risk of extirpation with one recorded breeding pair in 2015. This SPA has the lowest forest cover (33%) and an apparently high proportion of suitable foraging area (Moran & Wilson-Parr, 2014; Appendix 4 – 9). This indicates

that constraints in this area may not wholly be driven by gross habitat composition. Further investigation of the pressures recorded in this area is warranted to establish the drivers of the decline. Some of the apparently suitable areas of habitat identified by Moran & Wilson-Parr (2015) were recorded by observers as heavily grazed during fieldwork (T. Nagle, personal observation & B. O'Donoghue, personal communication). The hen harrier breeding population in the Mullaghanish to Musheramore area (traditionally 3-4 pairs) was largely confined to a few small areas of the SPA. Observers noted that forest maturation, fragmentation, heavy grazing of heather by sheep and recently constructed windfarms in the core breeding area may be contributory factors in the declines (T. Nagle & B. O'Donoghue, personal observation). Additionally, persecution may also be a contributory factor (B. O'Donoghue, personal communication; NPWS, 2015b).

The Slieve Beagh population has declined and exhibits a notable spatial redistribution resulting in the loss of breeding pairs to the Slieve Beagh – Mullaghfad – Lisnaskea SPA in Northern Ireland. Moran & Wilson-Parr (2015) reported a relatively high extent of both foraging and nesting habitat but survey visits and review of pressures indicates that the quality of the breeding habitats may be compromised largely by turf-extraction and recent burning. The former breeding stronghold on open moorland is currently not suitable for nesting hen harrier although occasional foraging birds were still recorded. There was no breeding evidence at any of the remnant historical heather nest sites (C. McGeough; J. Shannon; M. Ruddock, personal observations).

Despite apparently abundant foraging and nesting habitats (Moran & Wilson-Parr, 2015) external factors may be influencing the population in these areas. Extensive habitat remediation and interventions are probably required at both these SPAs to reverse the critical population declines and initially should be targeted to protect remaining pairs.

The Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPA complex and the Slieve Aughty Mountains SPA, similar to 2010 surveys (Ruddock *et al*., 2012), have both declined since 2005. There are also a relatively large number of wind turbines recorded in these two SPAs (n = 153 & 77 respectively; Appendices 4 - 9) and further analysis of any spatial associations and/or avoidance of windfarms by hen harriers would be desirable. The pairs found in both these SPAs largely nest in afforested or scrub sites and the Stack's complex has the lowest proportional usable forest age structure of all SPAs (Appendices 4 – 9) indicating that forest demographics may be a driver in this area. Survey work in 2015 noted that many current or formerly active harrier nesting and foraging areas in the West Limerick Hills are extensively used for turf extraction. Consequently, where such activity occurs, as well as habitat degradation there tends to be a high level of human activity related disturbance which may also be impacting on harrier foraging and nesting behaviour; and/or distribution.

The extent of usable forest habitat for nesting and foraging purposes is predicted to decline across all SPAs over the next 10 years (Appendices 4 - 9). The effects of this declining forest suitability may result in further population declines in the foreseeable future in these areas. Within the SPAs there is a need to undertake further spatial analyses of nest locations, habitat structure, habitat metrics and site specific pressures which may influence hen harrier ecology to inform management actions (see also review in Ruddock *et al*., 2012).

4.5 Breeding outcomes and habitats utilised

Breeding success varied considerably between different areas, however the variation is difficult to interpret especially as hen harrier breeding parameters can vary considerably between years (Irwin *et al*., 2008; Wilson *et al*., 2012). In 2015 the nest initiation rate recorded as 87% was higher than in 2010 (65.6%) (Table 18). Although this study was not specifically to investigate breeding parameters, if it is assumed that all confirmed pairs for which breeding initiation was not confirmed (13%) failed to breed (which includes six pairs not recorded to initiate a nest and eight pairs where it was unknown if a nest was initiated or not), then estimates of failure to initiate breeding were lower for the current study compared to those found by other Irish research e.g. 34.6% for all pairs studied and 21.3% for confirmed pairs and which varies between regions (O'Donoghue, 2010).

Fledging success per confirmed breeding pair in the present study (45.4%) is higher than reported for the two most recent national surveys, which recorded a fledging success of 39.1% and 43.9% in 2010 and 2005 respectively (Ruddock *et al*., 2012; Barton *et al*., 2006). This success rate is also higher than a fledging success of 37.5% recorded by Wilson *et al*., (2012) although some of these same data are used across studies. The recorded fledging success in 2015 is however lower than the 77- 82% reported for the first national survey (Norriss *et al*., 2002) as well as for other Irish studies (60%, Irwin *et al*., 2008; 65%, O'Donoghue, 2010). Fledging success estimates were at the lower range or lower compared to similar data from Scotland which ranges between 52% and 76% (Picozzi, 1984; Meek *et al*., 1998; Redpath *et al*., 2002a; 2002c; Amar *et al*., 2003; 2005; 2007) and within the range reported for the Welsh population (33-60%; Whitfield *et al*., 2008). Low estimates of this parameter have been linked to population declines and/or the effects of direct human interference on hen harrier populations (Meek *et al*., 1998; Green & Etheridge, 1999; Redpath *et al*., 2002; Amar & Redpath, 2002; 2005; Amar *et al*., 2003; 2005; Whitfield *et al*., 2008) and thus warrants further investigation and implementation of management to increase breeding success.

There were no visits undertaken to specifically record clutch sizes although one nest visit in the Slieve Blooms established that there were four recently hatched chicks and an unhatched egg (clutch size = 5; J. Monaghan personal communication). In the absence of additional data on clutch sizes a comparison

with previous studies and regions is not possible. The number of fledglings recorded per confirmed pair (0.94 young; Table 18) were higher than recorded in 2010 (0.81 young) and also higher than mean estimates both from Northern Ireland (0.87, Ruddock *et al*., 2008) and Orkney (0.82 young, Redpath *et al*., 2002; 0.68, Amar *et al*., 2007). However, the 2015 estimate is lower than elsewhere in Scotland (2.3 - 3.2 young, Watson, 1977, Redpath *et al*., 2002, Green & Etheridge, 1999), and Wales (1.1 - 1.9, Whitfield *et al*., 2008). O'Donoghue (2010) and Scott & Clarke (2008) report higher estimates of fledgling hen harriers in long-term studies (1.6 young and 1.9 young respectively) and other recent estimates from the Republic of Ireland were higher than recorded here (1.9 young Barton *et al*., 2006; 1.6 young Irwin *et al*., 2008). Since nest success rates are relatively high during this study but overall productivity is low compared to published results. This implies that either small numbers of eggs are being laid and/or few chicks are fledging. This may mean that pre-breeding factors affect clutch sizes (Simmons, 2000; Green & Etheridge, 2001; Amar *et al*., 2003; Amar *et al*., 2005; O'Donoghue, 2010) and/or that starvation or predation (O'Donoghue, 2010; Fielding *et al*., 2011; McMillan, 2014) are resulting in brood reduction prior to fledging. In some instances predation or starvation of partial broods were recorded in the Slieve Blooms and thus the management of these factors may help increase overall productivity and thereby may assist increasing the population in the future.

Following the methods of Ruddock *et al*., (2012) a similar population model for each SPA and the wider countryside was constructed using breeding parameters from 2015 (see Appendix 11). This model assumed age-specific annual survival estimates (Etheridge *et al*., 1997), that the populations were closed and is undertaken in the absence of any existing estimate of non-breeders in Ireland. Whilst other rates of survival are becoming available in Ireland from on-going marking and tagging schemes, the values used in this model are the same as those used in 2010 (Ruddock *et al*., 2012) in order to provide a comparable estimate of the population status. The model predicts a national deficit of 32.9 hen harriers from 2015 to 2016 since both inside the SPA network and outside the network had no surplus (-10.4 & -22.5 respectively).

The two smallest population SPAs (Mullaghanish to Musheramore & Slieve Beagh) were predicted to have a small surplus (+0.3 & +0.1 respectively) although in both sites these were due to a single successful breeding pair. Therefore, similar to 2010 modelling the hen harrier population does not appear to be self-sustaining and (assumed) mortality rates are greater than productivity. The population of hen harrier in Ireland therefore likely remains dependent on emigration from elsewhere and in the absence of this would likely continue to decline. In four of the six SPAs the deficit of hen harriers was less than in 2010 (Stack's Complex; Mullaghanish to Musheramore; Slieve Aughty; Slieve Beagh). This indicates that there may be some factors over the preceding five years which have improved productivity at these sites, however with a single year estimate, like this study, this could be complicated by inter-annual variation (Riffel & Gutzwiller, 2008) and a robust multi-year population

model for Ireland (e.g. Fielding *et al*., 2011; New *et al*., 2011) is desirable to provide confidence in the estimates of population dynamics.

As noted by Ruddock *et al*., (2012) the accuracy of the estimates generated by these models is expected to be low given the crude nature of the analysis and assumptions involved, particularly for survival estimates. The survival estimate may actually be considerably lower (0.16 first year survival; B' O'Donoghue, unpublished data) in Ireland than recorded in Scotland (Etheridge *et al*., 1997). Nevertheless this modelling analysis again indicates a possible dependency of the SPA populations on harriers breeding in the wider countryside, where there is no additional surplus, or from Northern Ireland or Great Britain. This raises the possibility that some of these populations could be acting solely as sinks (Newton, 1979; Pulliam, 1988; Newton, 1998; see also Irwin *et al.,* 2008; Ruddock *et al.,* 2008; O'Donoghue, 2010) incapable of maintaining regional and/or national hen harrier populations.

4.6 Pressures

Following the ad hoc recording of pressures and directly recorded threats in 2010 (Ruddock *et al*., 2012), it was desirable to collect data more systematically during the 2015 survey. In particular Ruddock *et al*., (2012) identified several factors considered as direct 'disturbance' at known hen harrier sites which included turf cutting, windfarms, power-lines, roads, vehicles, burning, human disturbance, agricultural activity, cattle (i.e. trampling), forestry operations, forest maturation, predation, scrub clearance, shooting and recreational activity.

During the 2015 survey the purpose was two-fold: to establish the occurrence and/or absence of pressures nationally and within regional populations and also to provide a baseline for further investigation of the likely or actual causes of declines or increases observed. It was not intended to collect data in order to establish the proximate causes of nesting or breeding failures, since some of these may not be readily detected by this national breeding survey e.g. predation or direct persecution. Rather it was intended to obtain information on the spatial occurrence and types of pressures which were apparent to the surveyors and recorded in the hen harrier breeding areas. During such a widespread survey with large numbers of fieldworkers it was possible to collect a vast amount of useful data. It is hoped that the collection of these data can inform more strategic and specific analyses of causes of regional and national declines or increases in the future. The pressure metrics could readily be recorded by field observers and inform policy makers of the recorded occurrence of pressures which may positively and/or negatively affect hen harriers.

The aim of the pressure analysis was to show the varying extent of pressures nationally, regionally and within SPAs. Sites may be severely impacted by one or two pressures while several areas may experience high levels of one or two pressures but which may have negligible impacts but the aim of

the analysis was to show the extent and types of cumulative impacts of pressures. It was noted that there may be varying levels of observer effort to record pressures comprehensively although submissions nationally were high and recorded from all survey areas.

Pressures varied extensively both nationally and regionally. The most frequently recorded pressures nationally (combined for both 500m and 2km zones; in order of magnitude) were related to (i) forestry management and use; (ii) access and recreation (paths, tracks, cycling tracks); (iii) predation (by mammals); (iv) reduction or loss of habitat features (removal of hedgerows, deep heather, scrub, walls, drains); (v) non-intensive grazing; (vi) roads and motorways and finally the category (vii) where no pressures were recorded. Some of these may cause acute responses and have either negative or positive proximate or long-term effects and others may require more long-term management and/or engagement with stakeholders to derive solutions.

Forestry management and use, was also noted to be associated with forest maturation by a large number of observers within the hen harrier breeding areas. The benefits and risks of forestry management and use have been extensively reviewed (NPWS, 2015) as part of the Hen Harrier Threat Response Plan (NPWS, in prep) and it will be important to identify the regional and/or site specific influences in order to derive effective conservation management tools within afforested areas. Access and/or roads may cause fragmentation (Trombulak & Frissell, 2000) but also facilitate disturbance and result in avoidance of these road networks (Tapia *et al*., 2004) which may lead to displacement or cause breeding failure (O'Donoghue, 2010). Establishing the proximate causes of disturbance at specific nesting areas would be useful for management and/or require widespread implementation of guidance for operations, activities, actions or management within hen harrier breeding areas (Currie & Elliot, 1997; Petty, 1998; Ruddock & Whitfield, 2007; Whitfield *et al*., 2008). Spatial analysis of road networks within hen harrier areas is desirable to more explicitly understand avoidance effects, if any.

It is possible the pressure of non-intensive grazing may have both a negative or positive impact whereby under-grazing may facilitate development of tall stands of heather suitable for nesting, but similarly the absence of grazing may lead to under-grazed, abandoned areas not suitable for either foraging and/or breeding in the absence of any management. Over-grazing can also have profound effects on breeding hen harrier (see Amar *et al*., 2011) and it is important to optimise levels of grazing within the landscape to benefit not only the provision of suitable nesting habitats but also so that grazing can affect prey species populations for the hen harrier (e.g. Vanhinsbergh & Chamberlain, 2001). The provision of suitable foraging in close proximity to nesting habitats remains a priority in Ireland to optimise hen harrier occupancy and breeding outputs (see Ruddock *et al*., 2008; Wilson *et al*., 2005; 2006a; 2006b; 2009; 2010; Fielding *et al*., 2011; O'Donoghue, 2011; Ruddock *et al*., 2012). The recording of non-intensive grazing by observers, several of whom linked this to the abandonment pressure code (A4; Table 5) in this study, may therefore indicate (i) the maintenance of traditional

grazing practices i.e. "extensive low-input agriculture" and/or (ii) that the effects of land or farm abandonment (Woodhouse *et al*., 2005; Haddaway *et al*., 2013; Plieninger *et al*., 2014) are evident within the hen harrier breeding range.

Predation (by mammals) was the sixth most frequently recorded pressure and was observed both directly (nest observations, remote camera monitoring and/or post visits) and indirectly (whereby observers recorded the presence of predators in close proximity to breeding areas). There were a number of observers who also report that nests were observed to fail before fledging i.e. with well-developed nestlings. That is, with intensive monitoring around predicted fledging dates this study found no evidence of successful fledged young at many sites which had previously been active. This was also supported by post breeding season visits to nests found remnants of predated nestlings. Predation can be a limiting factor in hen harrier nest success (Watson, 1977; Green & Etheridge, 1999; Whitfield & Fielding, 2009; O'Donoghue, 2012; Baines & Richardson, 2013; Hardey *et al*., 2013; McMillan, 2014). Management intervention through nest protection and/or legally sanctioned control of nest predators (e.g. fox or crows), physical barriers (such as temporary fencing around nests), and/or electronic or olfactory deterrents warrant further investigation and review of applicability and efficacy since these may maximise breeding productivity. It is recognised these may require scientific testing to prove effects and some methods may be labour intensive and/or prohibitively expensive and care would need to be taken to minimise disturbance. The recorded increases in hen harrier in parts of Leitrim, may be recently influenced by the implementation of wider upland and habitat management at Boleybrack Mountain, including predator control, although it would be necessary for further analysis to establish the direct effects and spatial associations of such management on hen harriers.

Published studies in Britain (Green & Etheridge, 1999; Baines & Richardson, 2013) indicate that provided no illegal killing of hen harriers occurs, predator management can positively influence hen harrier populations although results in the former study were not clear. Dissimilar to information from Britain on the effects of illegal killing or human interference (Meek *et al*., 1998; Green & Etheridge, 1999; Whitfield *et al*., 2008) this study did not record any incidences of illegal killing of hen harriers and this may not be considered a widespread issue in Ireland as it is elsewhere although it is recognised this study was specifically focussed at breeding areas, and thus may have under-detected such occurrences.

Persecution is often very difficult to detect by direct observation and nests were not explicitly checked after nest failure was detected. Further, direct illegal persecution of harriers in Ireland has been recorded in the past (The Kerryman, 2003; NPWS, 2015a; b; c) and anecdotal evidence suggests that there have been other recent instances of harrier persecution (NPWS, 2015; B. O'Donoghue, personal communication). It was also recently confirmed the shooting of a satellite tagged hen harrier (NPWS 2015a; b; c; B. O'Donoghue, personal communication) and it is conceivable that illegal killing may

occur during wintering periods or at winter roost sites rather than during the breeding season and therefore would not have been detected during the current surveys.

A number of sub-adult or immature males were noted at breeding sites in the Ballyhouras, Boggeraghs and Mullaghareirks. Most of these males were identified as third summer birds although the only successful pair in the Mullaghanish to Musheramore Mountains SPA consisted of a second summer male and second summer female (both one-year old birds). The presence of sub-adult birds in a breeding population (Whitfield *et al*., 2004a; 2004b; Radovic & Mikuska, 2009) can indicate issues with the wider population since adult birds may be lost and it is possible that persecution may be responsible. Further investigation is required to determine the numbers of sub-adult birds in the Irish breeding population.

The absence of any pressures was also a frequently recorded category by observers which reveals that not all areas are under pressure, or also that some effects may not be readily detectable by observers. Notably, pressures were recorded at both increasing and decreasing regional populations and as such further interpretation and analyses of each area are desirable to establish cause-effect relationships which is beyond the scope of this study.

In several parts of the east coast; including Wicklow; Louth; north and south Dublin Mountains; and Carlow, despite apparently suitable habitat observers reported high levels of pressures in the breeding season including military activity, recreational activity and recreational shooting activity (i.e. clay pigeon and/or range practice). Military manoeuvres were also found to be a likely cause of nest failure at one site in a designated army firing range in north Cork. These were recorded extensively by observers across these mountain ranges which may make much of the area unsuitable, despite suitable habitat, and result in the small number of observed sightings. Management of anthropogenic factors in these areas, and given the extent of apparently optimal habitat conditions in many parts of this eastern range, could possibly result in an increased population. Further engagement with the range of stakeholders involved in such activities would be necessary to explore this further.

The Boggeragh – Derrynasaggart; Stack's – Glanaruddery – Knockanefune – Mullaghareirk Mountains complex; the Ballyhouras and the Slieve Aughties had the greatest recorded pressure indices within regional areas. All of these areas were recorded to have declined from 2010. At the Boggeragh – Derrynasaggart ranges (which includes the Mullaghanish – Musheramore Mountains SPA) and based on the data received the most frequently recorded pressures were related to grazing, the reduction or loss of specific site features (heather, scrub, hedgerows, etc.) and predation by mammals which indicates that habitat factors may be operating in this area and specifically the removal of site features was considered to cause direct disturbance and compromise suitability of breeding habitats.

In the Ballyhouras and parts of the Nagles recreational disturbance was highlighted by observers as a pressure. Such disturbance (from quads and scramblers) was also recorded as causing habitat damage in the Special Area of Conservation (SAC; Natura 2000 site) within the Ballyhouras. Whilst not recorded specifically in 2015 within the Ballyhouras, there are recent (2014) records of breeding failures directly due to recreational disturbance and disturbance at one site due to forest thinning taking place during breeding (B. O'Mahony, personal communication, A. Mee, personal observation). One traditional heather nest site was apparently abandoned this year for the first time in recent times. In summary, the Ballyhouras continues to experience relatively high levels of recreational disturbance during the breeding season following the opening of a trail through the site and the associated increases in activity and access that has been facilitated which appears in part to unregulated and potentially damaging and/or causing disturbance to both habitats and hen harriers (A. Mee, personal observation).

Within the Stacks complex the most frequently recorded pressures were forest and plantation management & use and wind energy production (see Appendix 5). This is reflected within available data by the high forest cover (Moran & Wilson-Parr, 2015) and low proportional suitability of afforested habitat and relatively large number of wind turbines within the SPA boundary (n = 153). In West Limerick, within parts of the SPA, observers recorded widespread turf cutting within optimal harrier nesting and foraging habitats. The effects of these activities are considered mainly through loss of suitable habitat and disturbance to breeding associated with these activities and a least one nest in the Mullaghareirks was recorded to have failed as a direct result of disturbance caused by turf-cutting. Elsewhere in West Limerick, observers considered a decline in hen harriers near recently constructed windfarms particularly where the turbines were associated with simultaneous forest clear-felling but evidence of this would require further spatial analyses (e.g. Pearce-Higgins *et al*., 2009; 2012).

Both the Stack's complex and the Slieve Aughty Mountains have more than 50% forest cover and only a small proportion (9 – 15%) may be suitable for nesting (Moran & Wilson-Parr, 2015). Most frequently recorded pressures in the Slieve Aughty Mountain were paths, tracks, cycling tracks including non-paved forest roads; uncontrolled burning; utility & service lines and forest and plantation management and use. These pressures reflect a wide range of issues including recreation, land management, infrastructure development and forestry management. There appeared to be a positive association, although this was not statistically tested, and supported by behavioural observations, that habitat management (i.e. clearance) for power line infrastructure may provide corridors for movement and foraging by hen harriers within the forested landscape. The use of such corridors could prove useful to increasing connectivity with suitable nesting and foraging areas and particularly linking forested areas with open habitats which are shown to be used more frequently in Ireland (Ruddock *et al*., 2012; this study)

At Slieve Beagh, within the SPA, the pressures observed were primarily degradation of habitat through extensive, mechanised turf-cutting. Observers consider the traditional 'core' area as no longer suitable habitat due to extensive habitat loss and degradation largely due to turf extraction and few sightings were obtained from within the former moorland stronghold for the species. Historically there has been extensive burning of moorland in this area, and some further records of uncontrolled burning were recorded in 2015. Much of the moorland habitat is now probably beyond usefulness for nesting hen harriers where historical burning took place (M. Ruddock, personal observation). Some of the existing territories away from the historical core are also under pressure from encroaching turf cutting and is reported as the cause of failure in one nest at the western edge of the survey area. The eastern territory at Slieve Beagh has been continuously occupied since the late 1990s in a remnant deep heather bank on the outer edge of the plantation and remains relatively undisturbed. However this pair failed to breed successfully in 2015. It is notable that the plantation is steadily maturing around that locality.

Clearly hen harriers increasing or declining within or between sites or regional areas may be due to more than one cause, and indeed cause and effect is difficult to establish on the basis of the current data and likely to be considerably more complex and may be due to multiple interacting or competing factors.

4.7 Other research

In addition to collating information on hen harrier, observers also submitted sightings of a range of other species recorded within survey areas, most notably other raptors and rare upland species. Given the extensive survey effort focused on areas which are not otherwise routinely surveyed, the additional records provide valuable information on the occurrence and distribution of rare (e.g. hobby, golden eagle, marsh harrier) and/or under-recorded species (e.g. merlin), which can help inform future management, surveys and research initiatives. Of particular benefit were sightings of curlew recorded within the areas covered by hen harrier surveyors, which were submitted to the National Curlew Survey (coordinated by NPWS and BWI).

Only a single wing-tagged hen harrier was recorded during the survey in 2015. A male which was tagged in the nest in the Slieve Blooms in 2013 was observed in suitable habitat where possible breeding was recorded in the Slieve Aughties. The number of sightings of wing-tagged birds in 2015 was lower than 2010 when four wing tagged hen harriers were recorded. The low number of sightings of wing-tagged birds in both 2010 and 2015 may be a cause for concern, since this may indicate a low recruitment rate for Irish born harriers into the breeding population, which may be influenced by poor survival in the non-breeding period. The on-going collection of hen harrier survival and dispersal

data; through wing-tagging and radio/satellite telemetry remains an on-going priority for Irish hen harrier research (Ruddock *et al*., 2008; Reid *et al*., 2011), as do conservation efforts to address survival and recruitment of juveniles into the breeding population.

There were few post-fledging nest visits and/or feather and prey collections undertaken, with the majority of information collected from the Stack's, Glanaruddery, Knockanefune, Mullaghareirk Mountains. Although this additional research is not a primary objective of the survey, the collection of such data can prove very useful when sufficient time is allocated. However, the collection of feather samples for DNA analysis (Heap *et al*., 2011) would be highly desirable in the context of Irish hen harrier research to examine e.g. turnover, dispersal and connectivity with other populations to add to existing conservation knowledge and efforts. To facilitate increased collection of these additional data would likely require fewer squares to be monitored by each individual fieldworker thereby enabling the allocation of more time for such tasks.

Future surveys should be mindful of limiting resources by increased coverage of more, or unsuitable squares, to collect these additional data and in order that tasks would not be considered onerous by fieldworkers and also not compromise core survey coverage.

4.8 Conclusions & recommendations

The 2015 survey of breeding hen harrier in Ireland has shown a decline in the national population estimate since 2010. The maximum population estimate (157 pairs) equates to a decline of 8.7% since 2010 (172 pairs). Similar to 2010 (Ruddock *et al*., 2012), the number of possible pairs has increased. Survey effort and coverage in 2015 was increased from all previous national surveys and this can lead to biases when comparing previous population estimations.

Several methods were used in order to reduce the potential biases when comparing the national population estimates across successive national survey due notably to increases in coverage and effort. These subset analyses provide a means to standardise the comparison of numbers between years and reduce biases associated with increasing survey effort between surveys. In all survey years the numbers of confirmed breeding pairs declined but in some years the number of possible pairs increased between surveys particularly between 2005 and 2010, which may have been biased by increasing survey effort.

- The first subset comparison shows a decline of 16.4% over the last five years in the maximum population estimate;
- The second subset comparison shows a total decline of 9.7% between 2005 and 2015 in the maximum population estimates; and

- The third subset comparison shows an overall decline of 33.5% from 1998 – 2000 to 2015.

Additional to these subset analyses, the mid-point estimate of the each of national population estimates (Norriss *et al*., 2002; Barton *et al*., 2006; Ruddock *et al*., 2012; this study) was used to calibrate the population range and aimed to reduce bias from increasing survey effort between years.

- The mid-point population estimates from all the national surveys shows an increase from 1998 – 2000 to 2015 (14.7%) and a decline from both 2005 (-7.0%) and 2010 (-11.7%) to the current mid-point population in 2015.

Therefore, accounting for biases which may arise from changes in survey effort, despite increasing survey effort in the 2015 survey, there has been no observed increase in the size of the breeding population. If the survey effort had decreased between years there would be greater concern over the population estimate, but rather with increasing survey effort the 2015 population estimate can be considered to be robust.

Whilst the intention to provide a randomised, statistical method of population estimation was desirable (see Ruddock *et al*., 2012), due to potential biases in survey visit coverage and submission of data for some of these random squares, it was not possible to provide this additional estimate in the timeframe required for reporting. This method warrants further investigation and analysis since outstanding data may be accessible and a high level of data from coverage of these squares was actually obtained (83%).

There has been an increase in recorded distribution since the last survey in 2010 particularly with the number of possible pairs and whilst some of this may be due to increasing survey effort, some of this may be due to redistribution from pairs previously recorded from within core breeding areas this may indicate a shifting range from formerly suitable areas to other areas which may be less suitable and hence greater proportion of possible pairs recorded in the population compared to the previous surveys.

In some areas there appear to have been some acute declines since previous surveys with the loss of up to six pairs in some individual survey squares since 2010. Whilst some of these losses may be explained, in part, due to apparent redistribution within and/or between regional populations, the total numbers recorded nationally has declined. Therefore it is not possible to explain all regional declines by movements or redistribution. Therefore a net decrease is apparent and robustly supported by several methods of analysis. The understanding of factors causing acute declines in some of these areas warrants further investigation with a view to remediation and/or amelioration measures. Encouragingly, some regional areas appear to have increased since the last survey, and whilst some of these increases might be explained by redistribution from other declining areas, the factors facilitating apparently positive population responses in those areas, such as Donegal, Leitrim, Devilsbit-

Slievefelim-Silvermines-King Hill, Knockmealdown-Kilworth-Comeraghs and the Slieve Blooms, also warrant further investigation and analysis.

The available evidence suggests that the status of hen harrier populations in Ireland's SPAs continue to decline. There is still a large portion of the national population within the SPAs (44%; 69 of 157). However, the overall population has decreased particularly since 2010. Thus the populations remain vulnerable to external or additive mortality factors or pressures and some of SPAs and the wider countryside, may be operating as 'sink' populations. Two of the SPAs in particular, Mullaghanish to Musheramore Mountains and Slieve Beagh, have declined considerably and given their small population sizes may not continue to be viable in the long-term without urgent intervention and remedial actions. Similarly at the Slieve Aughties there have been extensive and widespread declines since 2005 (27 pairs) to 2010 (23) and the rate of decline does not appear to have slowed to 2015 (14 pairs). The rate of decline at this site has actually increased from 15% (2005 – 2010) to 39% (2010 – 2015) between recent surveys. Whilst the Stack's to Mullaghareirk Mountains, West Limerick Hill and Mount Eagle have declined since the 2005 figures used for designation, the rate of this decline appears to have slowed since this population appears largely stable between 2010 and 2015 (29 to 28 pairs). However the low rate of breeding success and high levels of recorded pressures require further investigation and monitoring and would be beneficial to producing site specific management plans for each SPA to develop and implement required conservation action. Analysis and reporting of annual monitoring data in these areas would be beneficial from intervening years e.g. between 2011 and 2014, and in the future, to understand trends between national surveys.

It is necessary that an integrated management plan should be undertaken. This should account for all regional and site specific factors to help provide positive conservation management. Remote monitoring of hen harrier habitat conditions and classification (Moran & Wilson-Parr, 2015) are extremely useful, but field observation utilising some of the maps generated from Moran & Wilson-Parr (2015) found either recently observed pressures and/or activities on site that compromised the suitability of the habitats within the SPAs which may not be readily detectable by remote monitoring e.g. quality of the heath / bog habitats. The further integration of remote and field based monitoring and research is important in establishing the conditions and determining whether management interventions are required in order to maximise quality and quantity of suitable habitats.

There was a large amount of information derived on pressures in hen harrier breeding areas. Whilst there may be some biases in recording effort amongst observers and at specific sites the pressure metrics recorded by field observers is useful in helping to identify factors influencing hen harriers in the breeding areas. This study would urge caution in attempting to attribute cause and effect with any of the observed pressure to declines or increases in any of the hen harrier breeding areas since there may be many causal factors which are interlinked but it is hoped these can provide a foundation of

information on factors which may be operating nationally, regionally and within the SPA network and allow a prioritisation of likely risk for conservation managers and stakeholders. It is recommended also that further strategic spatial analysis of the pressures are undertaken in order to further inform management requirements.

The data derived on pressures in this study may assist in identifying specific areas affected by each of the pressure categories and could assist with identifying spatial species management measures. Further strategic spatial analysis of data such as wind turbine locations, proximity to forest plantations or open foraging areas and landscape corridors are highly desirable. These should be focused to establish metrics or impacts on breeding output and breeding locations in order to optimise the breeding populations of hen harriers. There remains an on-going requirement to investigate these factors further and adopt management targeted to optimise hen harrier breeding habitats and maximise breeding productivity and success in order to increase the breeding population, for which pressures and actions taken to benefit the populations may be site specific.

It is necessary both within SPAs and, also at the regional and national levels, to deal with pressures which can be readily regulated on a site or regional specific basis with a view to implementing management to stabilise and then reverse declines. The implementation of management should be targeted to increase the numbers of hen harriers that initiate breeding as well as productivity (e.g. via nest protection), which could then in turn facilitate an increase in the breeding populations. This process requires extensive consultation, engagement and agreement for the optimum management of the hen harrier population and its habitats.

It is recognised that sectoral pressures may vary within regions and between regions and be a combination of factors which may be additive and/or operate in either negative or positive directions temporally and spatially. Assessment of pressures and site specific factors will be greatly facilitated by the wider production of existing hen harrier and habitat datasets being undertaken by the NPWS Hen Harrier Threat Response Plan (NPWS, in prep). Further strategic analysis of population trends and constraints across a range of spatial and temporal scales by integrating the updated survey data and pressures information is desirable.

Socially and politically, there is awareness nationally that this species in coming under increasing pressure from different sectors and stakeholders in Ireland (see NPWS, 2015). This has been highlighted repeatedly in recent media particularly during 2013 to 2015 inclusive. Specifically, hen harrier conservation will be achieved through optimisation and availability of suitable conditions for hen harriers at the breeding and wintering sites. By utilising up-to-date metrics of distribution and abundance, evidence based targeted conservation actions for national and regional populations would be enabled and should be implemented through a national as well as site specific management plans.

Importantly it would also raise public awareness throughout Ireland of the pressures and/or threats faced by hen harriers and the conservation efforts that are required to overcome these.

The latter action is fundamentally important to encourage adoption by local communities, land owners and managers for the future of the hen harrier as an iconic species of Ireland's unique upland landscapes and in valuing the hen harrier as a species, within its landscape and associated Natura 2000 sites (NPWS, 2014). The spatial data collected by surveys such as this provides the basis for such management actions to address these frameworks hence the on-going requirement and utility of national surveys to underpin management decisions.

It is therefore important in light of this ongoing analysis and current stakeholder and media pressures and for the future of hen harrier conservation that an updated survey be completed within the next five years to identify changes where/if they occur. These surveys aim to maximise the engagement opportunities presented via volunteer and public engagement networks to maximise not only survey participation but also facilitate engagement with the wider public and the landowners where hen harriers occur.

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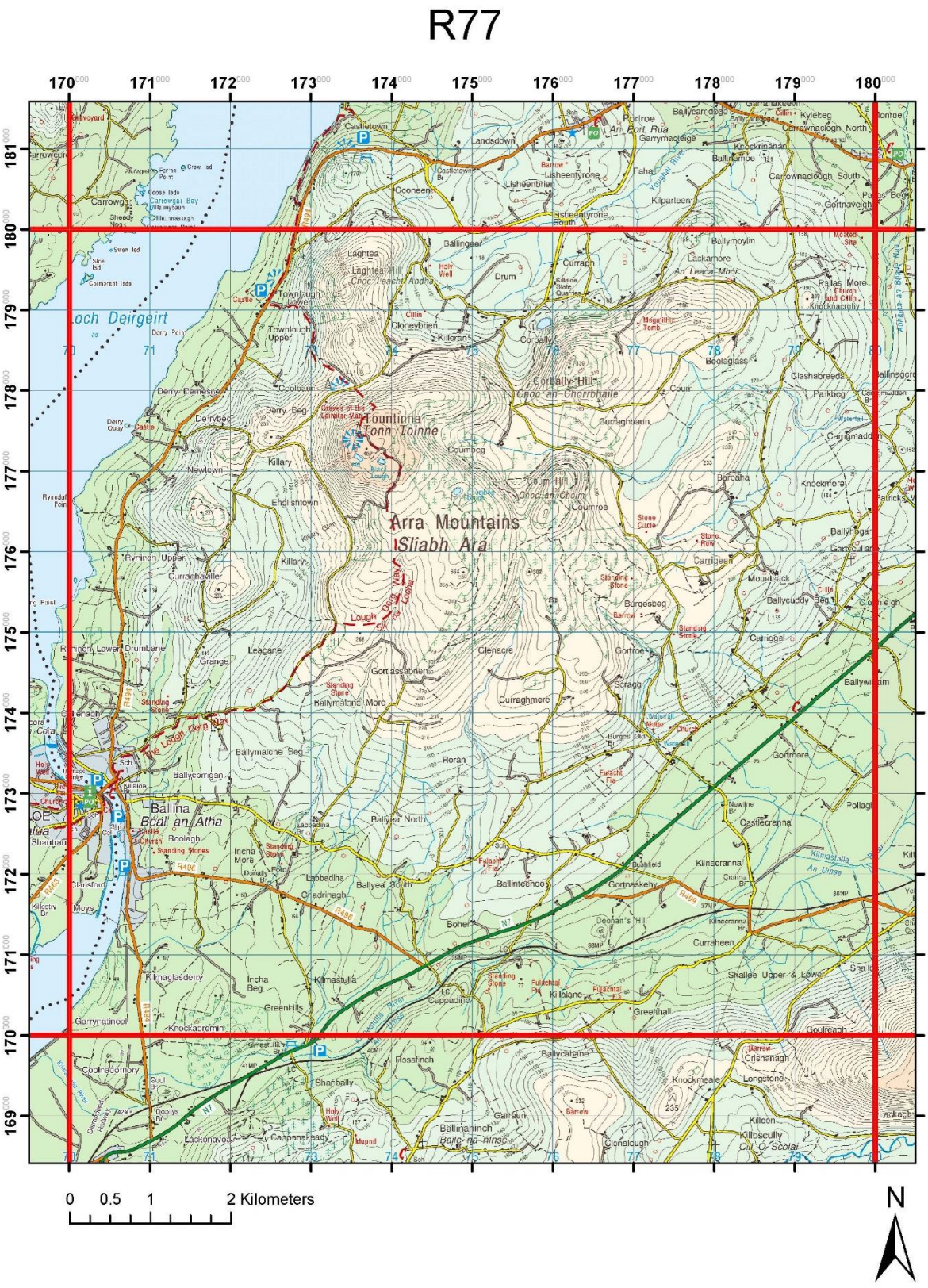
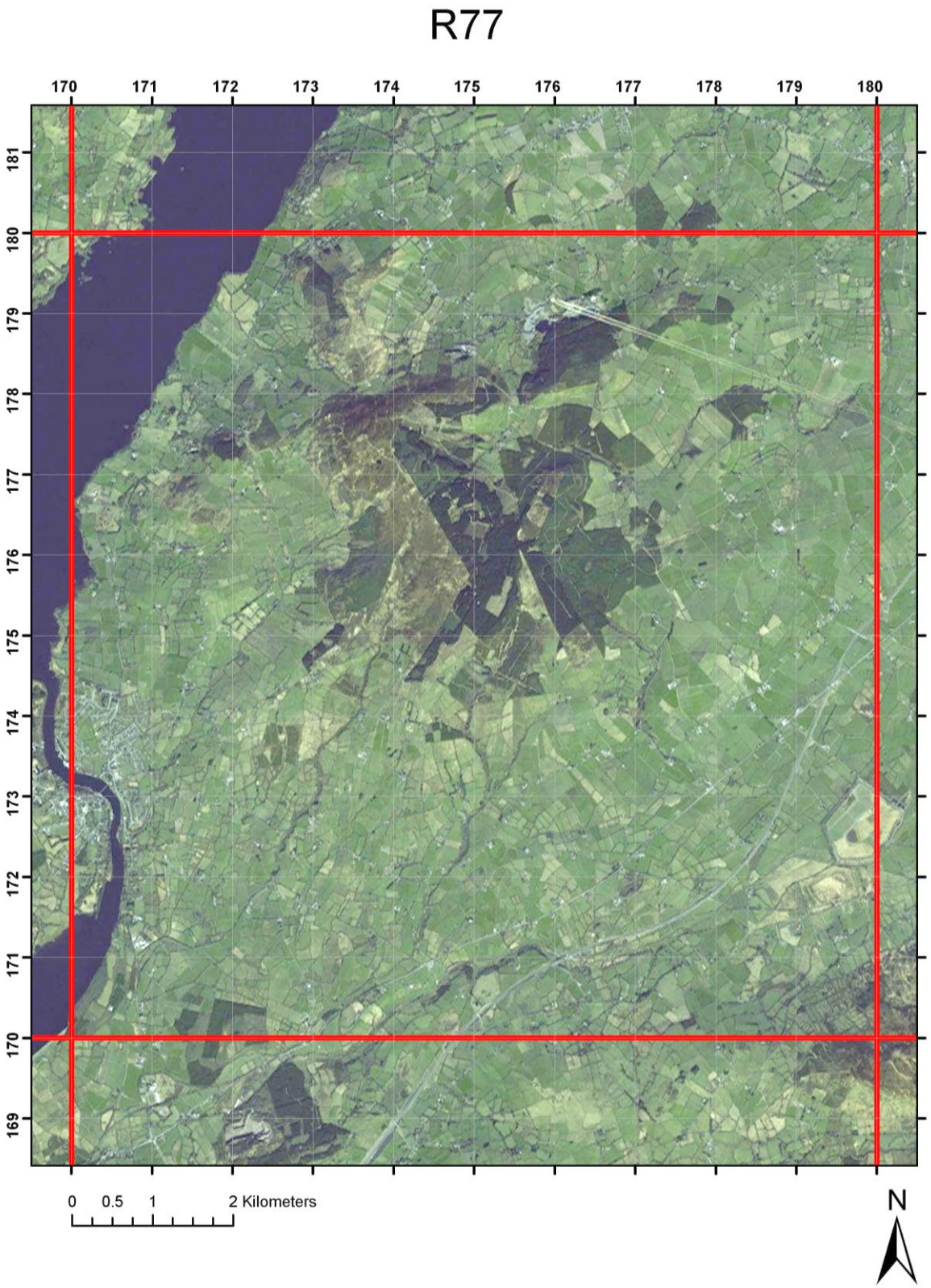
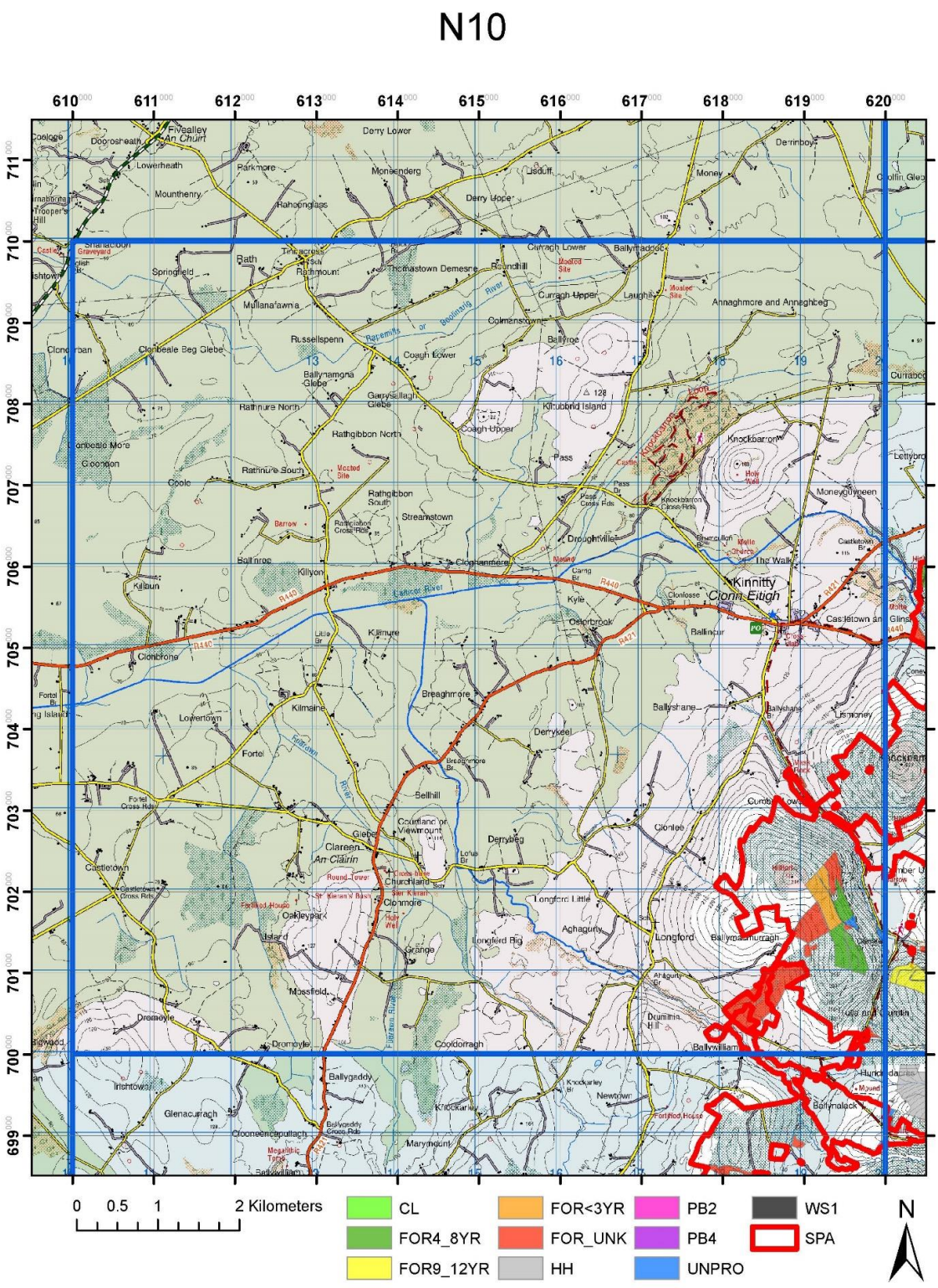
Appendix 1. 10km square map produced for use during surveys



Appendix 2. 10km square map produced from orthophotography for use during surveys



Appendix 3. 10km square map produced from habitat map derived from Moran & Wilson-Parr (2015) for use during surveys



Appendix 4. Mullaghanish to Musheramore Mountains SPA

Site code: 004162

Location: Co. Cork

Area: 4,975.6ha

Breeding parameters

In 2015 this SPA held one breeding pair of hen harrier. This equates to 0.06% of the national population and 1.4% of the SPA network population.

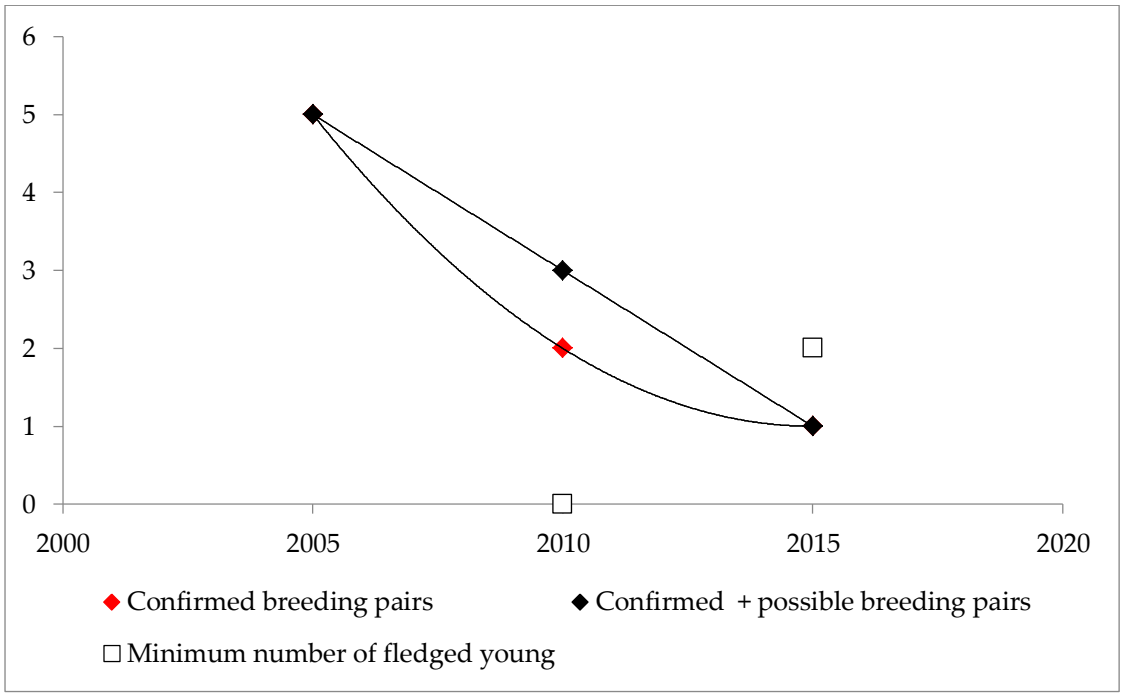
The number of pairs classed as confirmed breeders as a proportion of the site's breeding population equates to 100% (since only one pair was located) which is higher than both the national proportion (69%) and the total SPA proportion (74%).

Breeding success of confirmed pairs in 2015 was estimated to be 100% i.e. one pair at this site which is higher than the national estimate (at 45%) and higher than the estimated rate for the total SPA population (at 49%).

Breeding productivity was estimated at 2.0 fledged young per successful pair. This is lower than national estimate (at 2.1 young) and the total SPA population (at 2.2 young).

This SPA produced 2 fledged young in 2015. This equates to 1.9% of the total minimum number of fledged birds in Ireland and represents 3.6% of the total SPA population of fledged birds.

Figure 4a. Breeding parameters recorded over recent surveys for the Mullaghanish to Musheramore Mountains SPA.



Population in 2005	Population in 2010	Population in 2015	% change in total population since 2005
5 pairs	2-3 pairs	1 pair	-80.0%

Habitat composition & wind turbines

Technical Note:

Based on remote sensing techniques Moran & Wilson-Parr (2014) analysed aerial photography taken in 2013 and in conjunction with several existing geospatially referenced data sets (including the national forest inventory) constructed habitat maps of the breeding hen harrier SPA network. These habitats can be compiled into various categories relevant to hen harrier conservation and such categories can be broadly described as suitable, unsuitable and forested. For example, the suitable category includes rough grassland, blanket bog and scrub whilst improved grassland is considered to be unsuitable. This can be viewed online at http://www.npws.ie/maps-and-data/habitat-and-species-data/hen-harrier

It should be noted that due to the constraints of the remote survey methods no assessment of the quality of the habitats was undertaken. Therefore, and for example, the habitat category heath which is broadly considered to be suitable breeding habitat for hen harrier may be unsuitable due to damage e.g. caused by excessive burning at certain locations. Forest habitats represent both a foraging and nesting resource for harriers during the breeding season. However the usefulness of this habitat is largely determined by the degree of openness. Harriers use pre-thicket forests but their usefulness typically declines as the forest matures (for more information see NPWS, 2015).

During these habitat analyses (Moran & Wilson-Parr, 2014) spatial data was also collated on the extant wind turbines within and near the SPAs during 2013. It was not possible to identify the delineations between windfarm units per se as these may be contiguous. However individual turbines were readily visible in the aerial photography and spatial locations were thus available for spatial analysis. These data were reviewed in this study to establish the number of turbines within the SPA boundaries and within 500m of the SPA boundaries.

This SPA (based on Moran & Wilson-Parr, 2014) has between 31.7 – 33.3% suitable nesting habitat and 64.3 – 65.8% suitable foraging habitat. There are 1653.4ha (or 33.3% of total SPA area) in forest or woodland cover of which 500.7ha – 574.4ha (10.1 – 11.6%) are classed as suitable for nesting hen harriers.

A breakdown of foraging habitats, following Moran & Wilson-Parr (2014) is provided (Figure 4b) whilst based on an analysis contained in NPWS (2015) estimates the variant in the usefulness of the forest estate for both nesting and foraging purposes at this site over a 45 year period is shown (Figure 4c).

Figure 4b. Foraging habitat status based on Moran & Wilson-Parr (2014) and NPWS (2015).

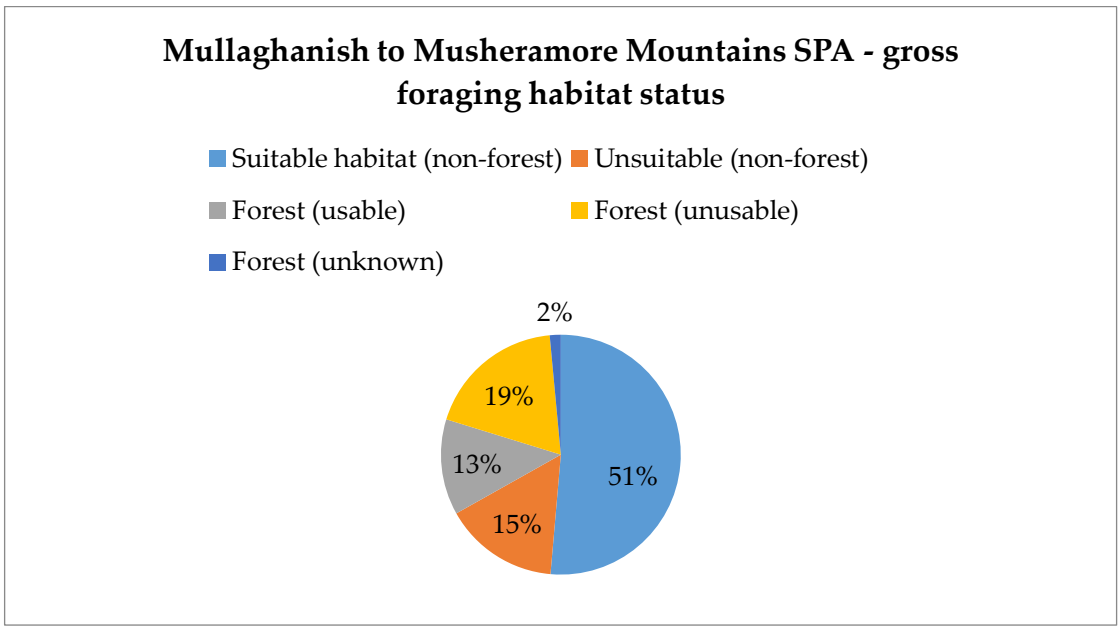
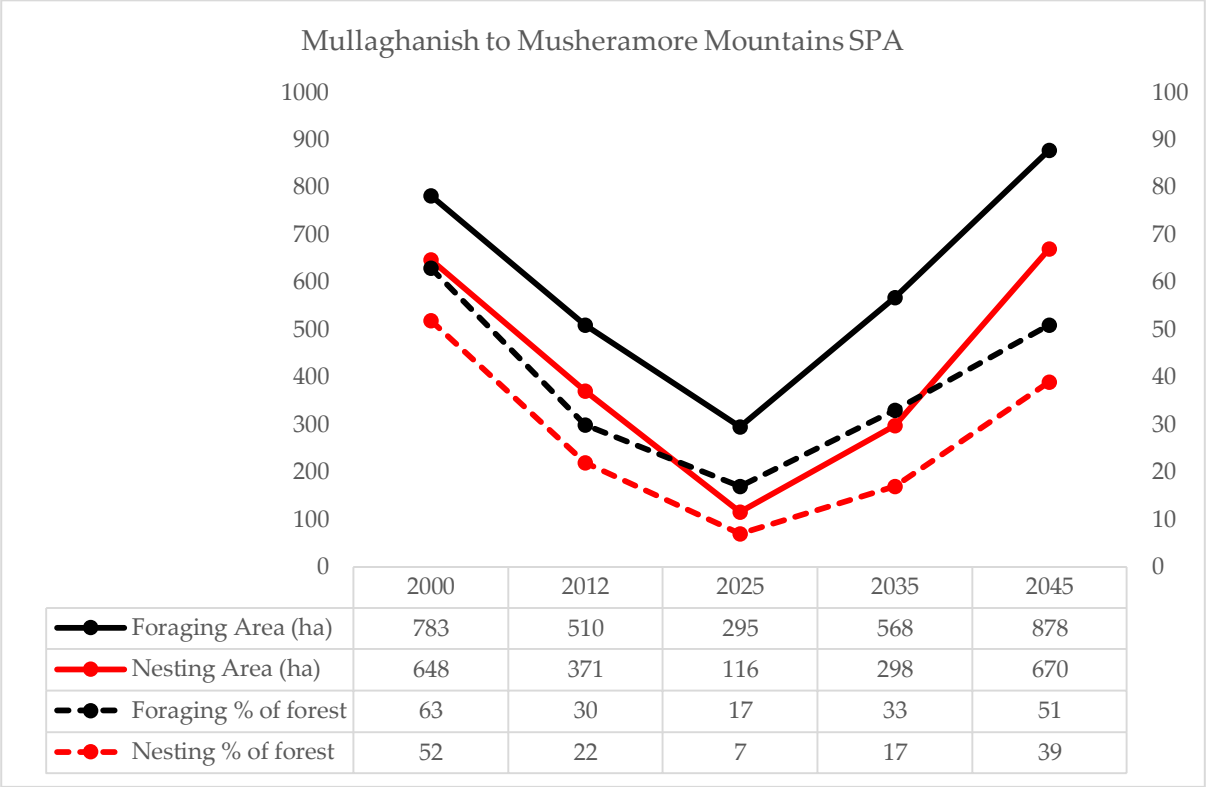


Figure 4c. Foraging and nesting habitat area and suitability based on NPWS (2015).



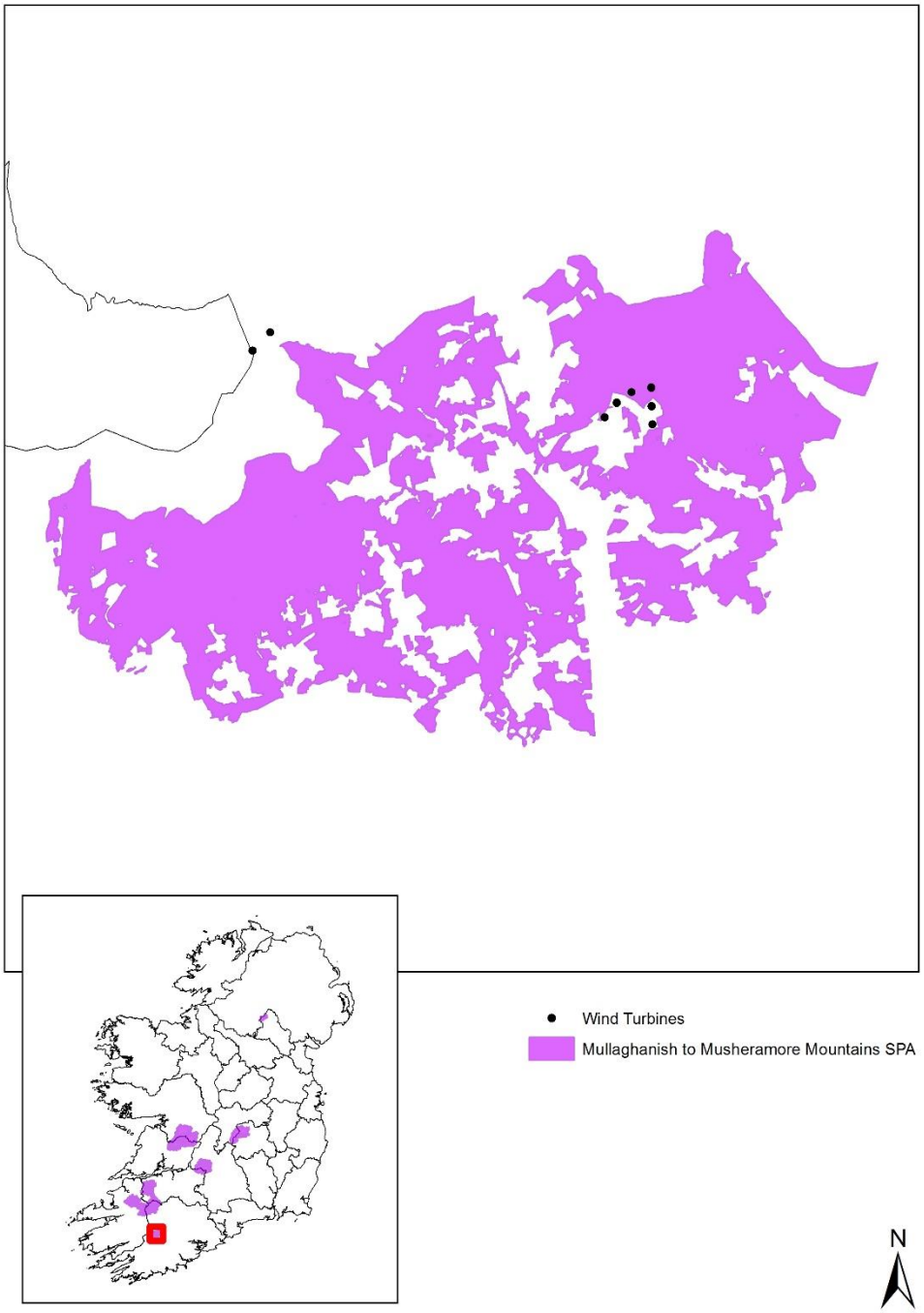
	2000	2012	2025	2035	2045
Foraging Area (ha)	783	510	295	568	878
Nesting Area (ha)	648	371	116	298	670
Foraging % of forest	63	30	17	33	51
Nesting % of forest	52	22	7	17	39

There are two wind turbines located within the SPA boundary and six others within 500m of the boundary (see Figure 4d).

Pressure monitoring

Within the 10km squares near the SPA there were 19 pressures recorded by fieldworkers including A2, A4, A5, A6, A8, B1, B2, B3, B7, C3, D1, D2, D3, D5, E1, G4 J3, J7, X. Most frequently recorded pressures were B2 (forest and plantation management & use); A5 (intensive grazing) and A2 (agricultural intensification).

Figure 4d. Spatial distribution of wind turbines within the SPA boundary and <500m from the SPA boundary. Locations of turbines derived from 2013 orthophotography (NPWS, unpublished data).



Appendix 5. Stack's to Mullaghareirk, West Limerick Hills & Mount Eagle SPA

Site code: 004161

Location: Co. Cork, Co. Kerry & Co. Limerick

Area: 56,627.2ha

Breeding parameters

In 2015 this SPA held 23-28 breeding pairs of hen harrier. This equates to 17.8% of the national population and 40.6% of the SPA network population.

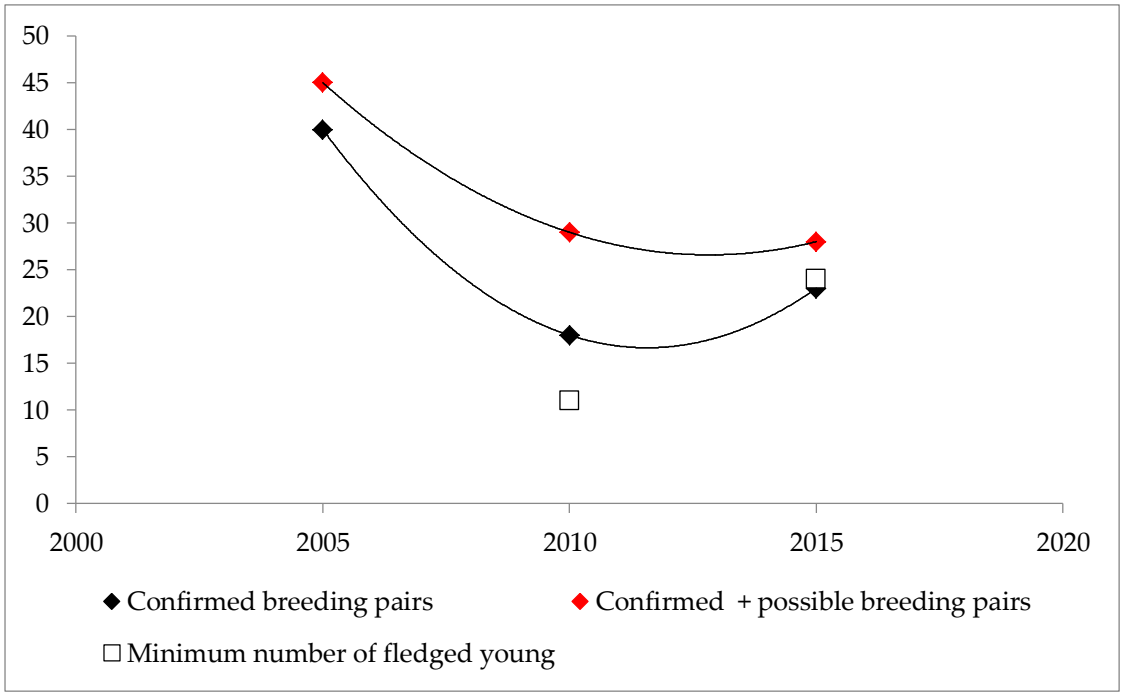
The number of pairs classed as confirmed breeders as a proportion of the sites breeding population equates to 82% which is higher than both the national proportion (69%) and the total SPA proportion (74%).

Breeding success of confirmed pairs in 2015 was estimated to be 47.8%, which is higher than the national estimate (at 45%) and lower than the estimated rate for the total SPA population (49%).

Breeding productivity was estimated at 2.18 young per successful pair (n = 11). This is higher than the national estimate (at 2.1 young) and lower than the total SPA population (at 2.2 young).

This SPA produced 24 fledged young in 2015. This equates to 23.5% of the total minimum number of fledged birds in Ireland and represents 42.9% of the total SPA population of fledged birds.

Figure 5a. Breeding parameters recorded over recent surveys for the Stack's to Mullaghareirk, West Limerick Hills & Mount Eagle SPA.



Population in 2005	Population in 2010	Population in 2015	% change in total population since 2005
40-45 pairs	18-29 pairs	23-28 pairs	-37.7%

Habitat composition & wind turbines

This SPA (based on Moran & Wilson-Parr, 2014) has between 27.8 – 33.3% suitable nesting habitat and 51.3 – 56.8% suitable foraging habitat. There are 28,873.4ha (or 51% of total SPA area) in forest or woodland cover of which 5,299.8ha – 8,388.7ha (9.4 – 14.8%) are classed as suitable for nesting hen harriers.

A breakdown of foraging habitats, following Moran & Wilson-Parr (2014) is provided (Figure 5b) whilst based on an analysis contained in NPWS (2015) estimates the variant in the usefulness of the forest estate for both nesting and foraging purposes at this site over a 45 year period is shown (Figure 5c).

Figure 5b. Foraging habitat status based on Moran & Wilson-Parr (2014) and NPWS (2015).

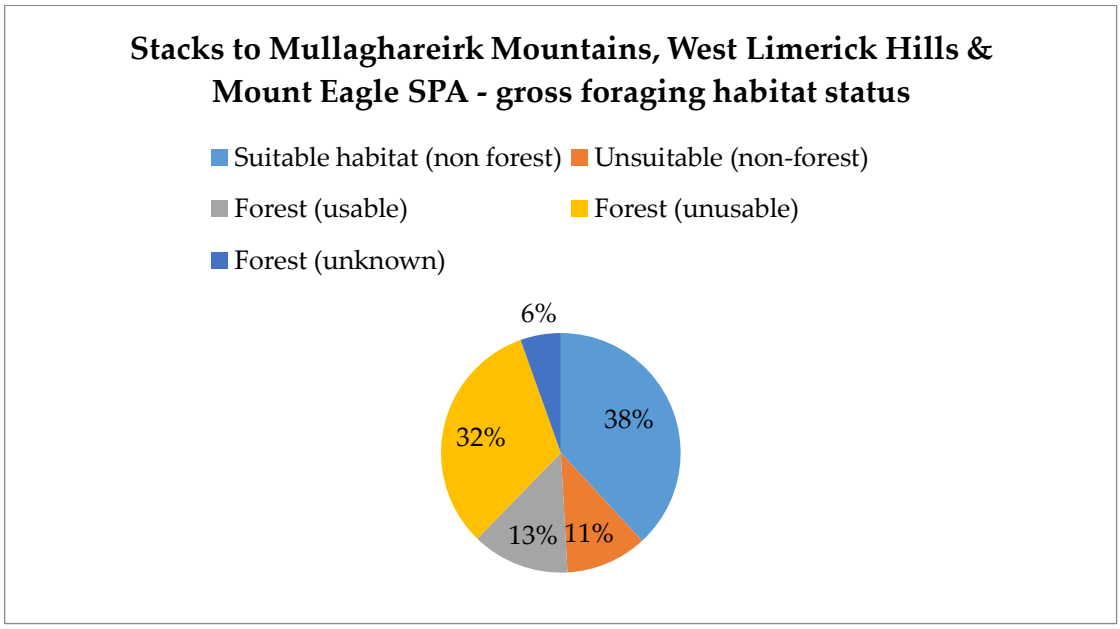
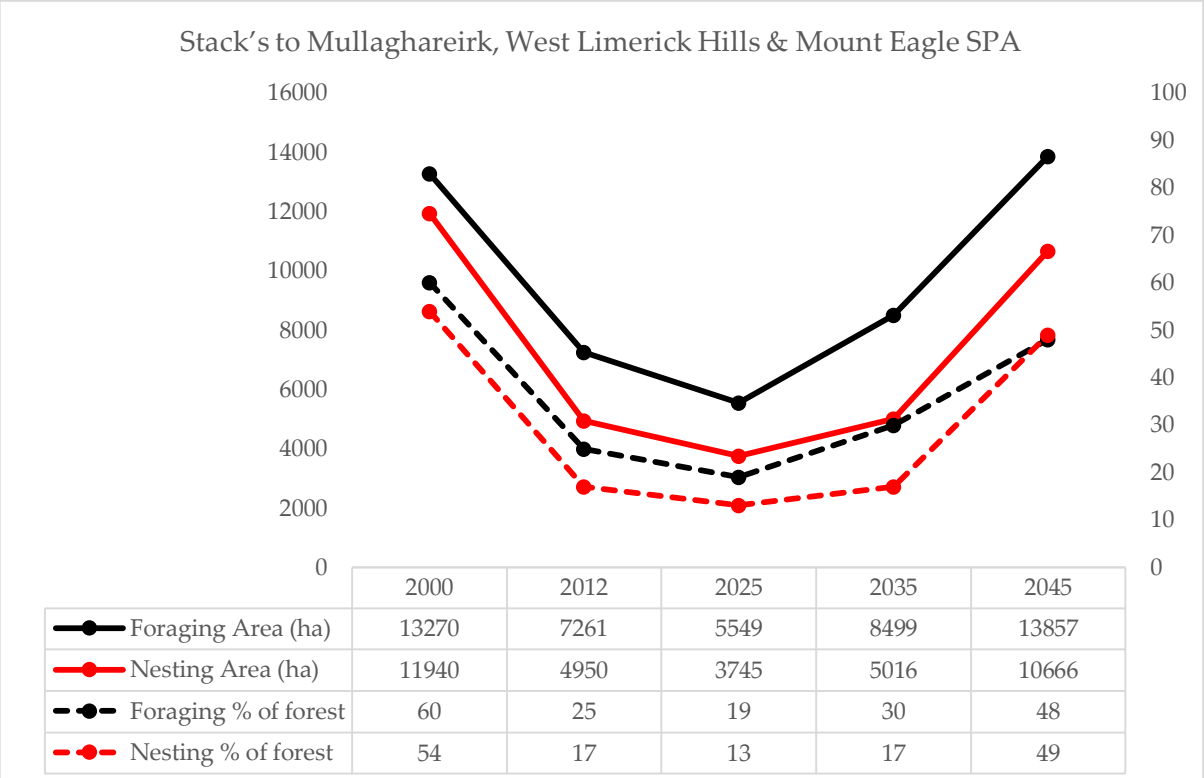


Figure 5c. Foraging and nesting habitat area and suitability based on NPWS (2015).



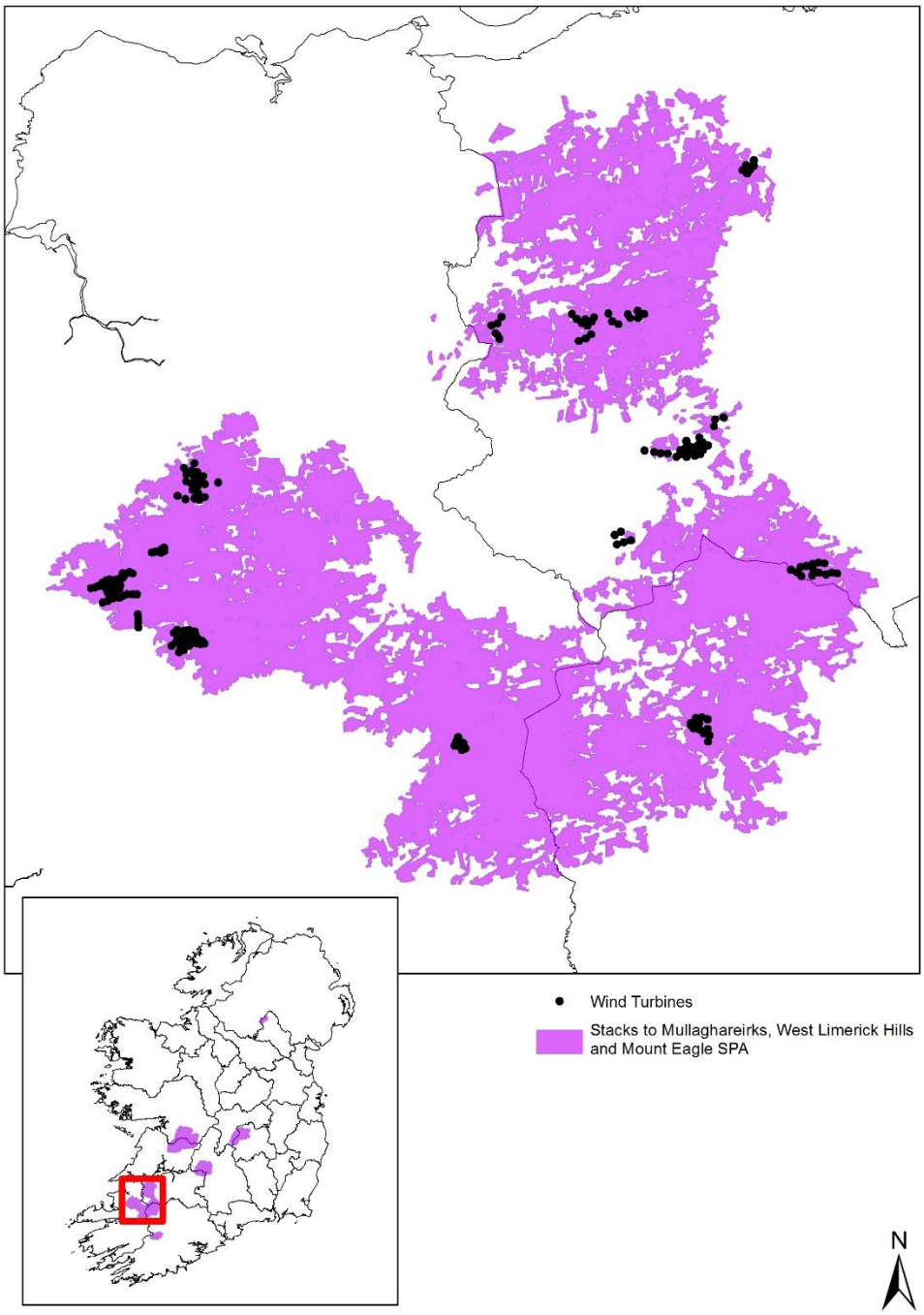
	2000	2012	2025	2035	2045
Foraging Area (ha)	13270	7261	5549	8499	13857
Nesting Area (ha)	11940	4950	3745	5016	10666
Foraging % of forest	60	25	19	30	48
Nesting % of forest	54	17	13	17	49

There are 153 wind turbines located within the SPA boundary and 38 others within 500m of the boundary (see Appendix 5d).

Pressure monitoring

Within the 10km squares near the SPA there were 29 pressures recorded by fieldworkers including A2, A4, A6, A7, A8, A9, B1, B2, B3, B4, C1, C2, C3, D1, D2, D3, E2, F1, G1, G4, G5, J2, J3, J5, J7, K1, K2, X, O. The other category made specific reference to forest maturation as a key pressure within the B2 category. Most frequently recorded pressures were B2 (forest and plantation management & use) and C3 (wind energy production).

Figure 5d. Spatial distribution of wind turbines within the SPA boundary and <500m from the SPA boundary. Locations of turbines derived from 2013 orthophotography (NPWS, unpublished data).



Appendix 6. Slievefelim to Silvermines Mountains SPA

Site code: 004165

Location: Co. Limerick & Co. Tipperary

Area: 20,909ha

Breeding parameters

In 2015 this SPA held 4-10 breeding pairs of hen harrier. This equates to 6.4% of the national population and 14.5% of the SPA network population.

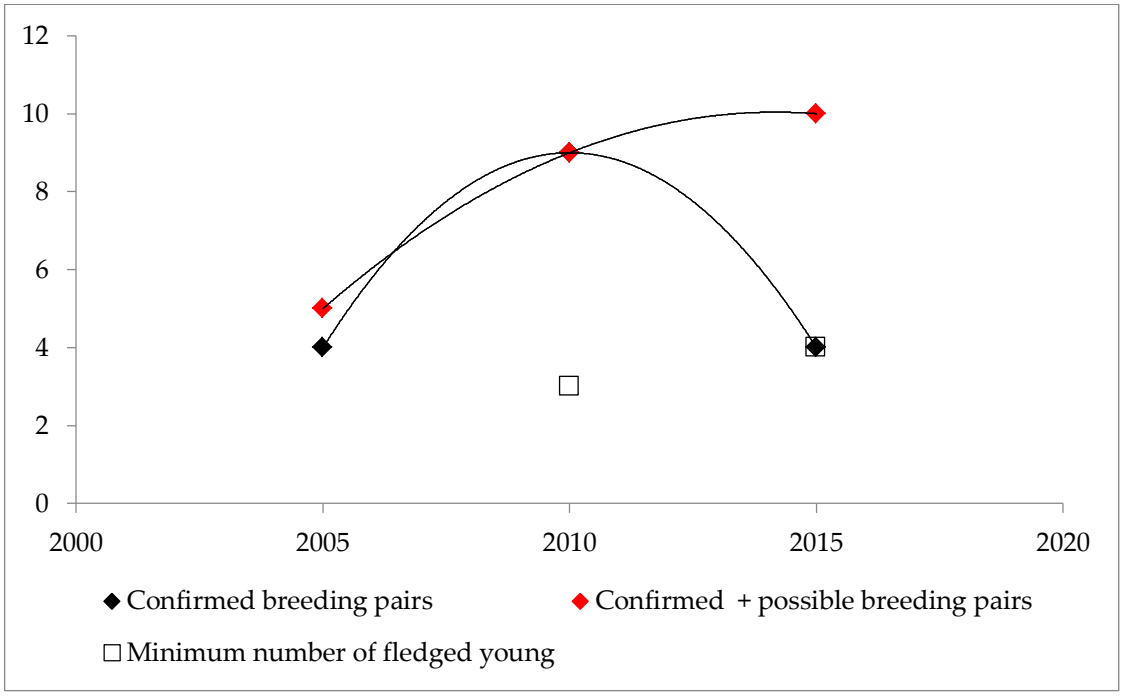
The number of pairs classed as confirmed breeders as a proportion of the site's breeding population equates to 40% which is lower than both the national proportion (69%) and the total SPA proportion (74%).

Breeding success was 50% of confirmed pairs in 2015 was estimated to be 50% which is higher than the national estimate (at 45%) and the same as the estimated rate for the total SPA population (at 49%).

Breeding productivity was estimated at 1.5 fledged young per successful pair. This is lower than the national than national estimate (at 2.1 young) and the total SPA population (at 2.2 young).

This SPA fledged 3 young in 2015. This equates to 2.9% of the total minimum number of fledged birds in Ireland and represents 5.4% of the total SPA population of fledged birds.

Figure 6a. Breeding parameters recorded over recent surveys for the Slievefelim to Silvermines Mountains SPA.



Population in 2005	Population in 2010	Population in 2015	% change in total population since 2005
4-5 pairs	9 pairs	4-10 pairs	+100.0%

Habitat composition & wind turbines

This SPA (based on Moran & Wilson-Parr, 2014) has between 28.2 – 31.3% suitable nesting habitat and 54.0 – 57.1% suitable foraging habitat. There are 11,201.9ha (or 53.6% of total SPA area) in forest or woodland cover of which 2,754.1ha – 4,401.7ha (13.2 – 16.3%) are classed as suitable for nesting hen harriers.

A breakdown of foraging habitats, following Moran & Wilson-Parr (2014) is provided (Figure 6b) whilst based on an analysis contained in NPWS (2015) estimates the variant in the usefulness of the forest estate for both nesting and foraging purposes at this site over a 45 year period is shown (Figure 6c).

Figure 6b. Foraging habitat status based on Moran & Wilson-Parr (2014) and NPWS (2015).

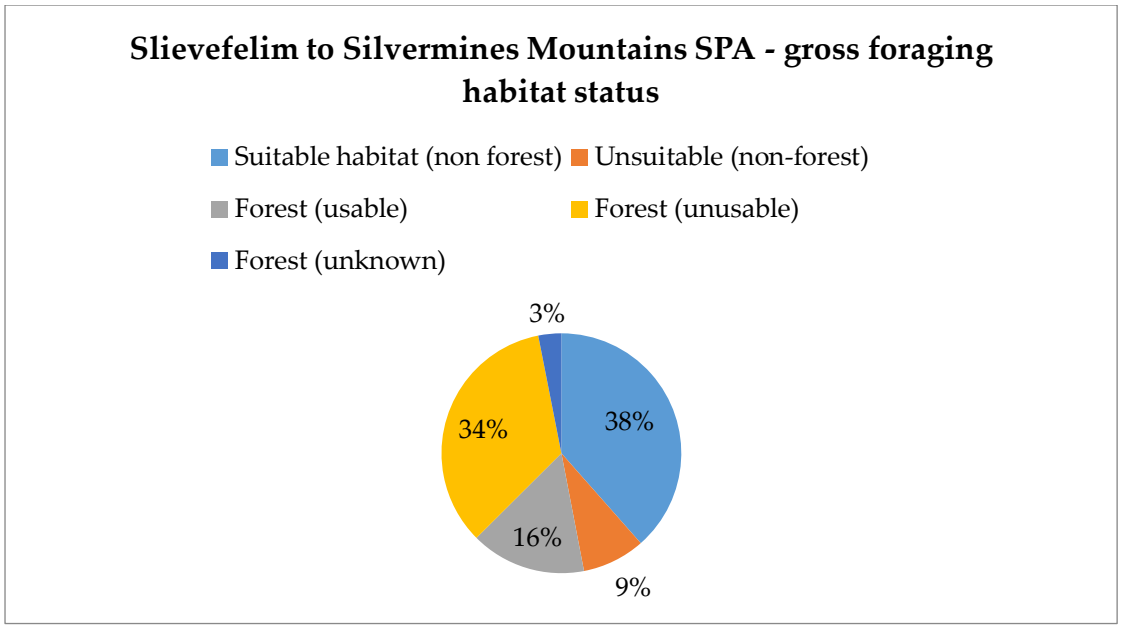
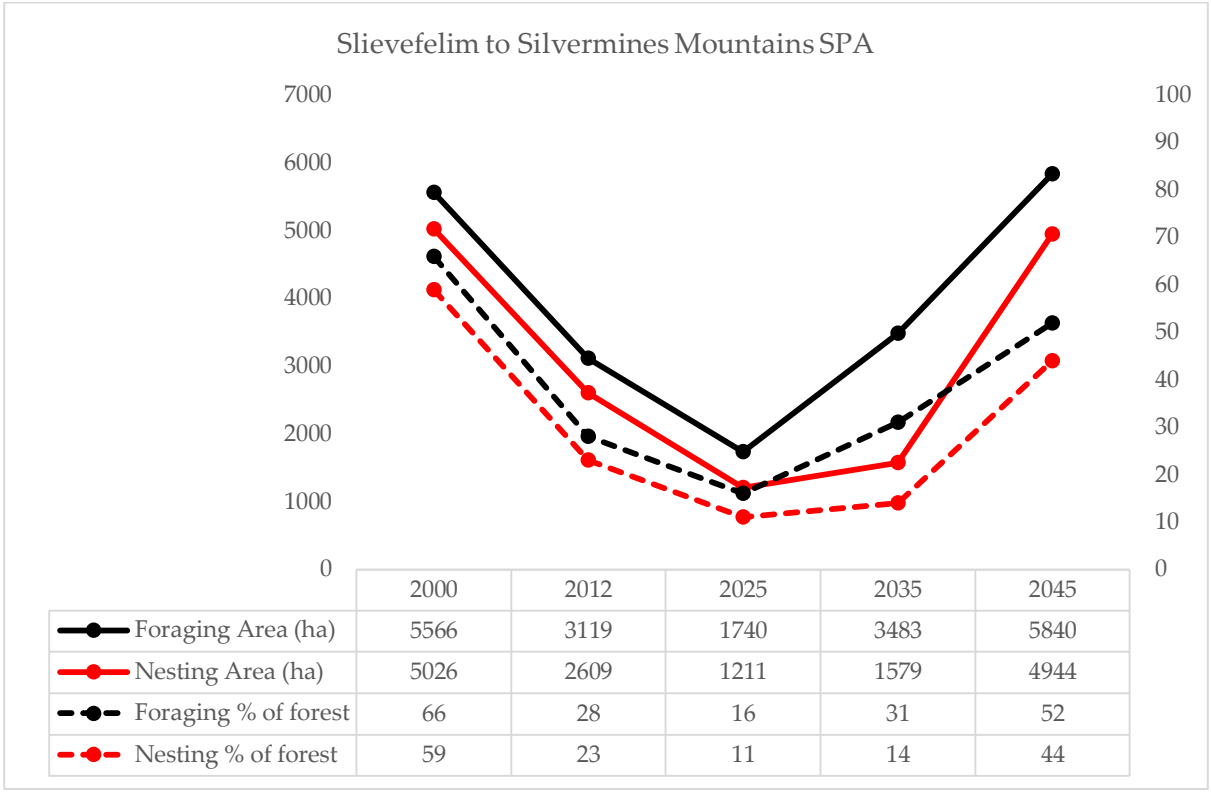


Figure 6c. Foraging and nesting habitat area and suitability based on NPWS (2015).



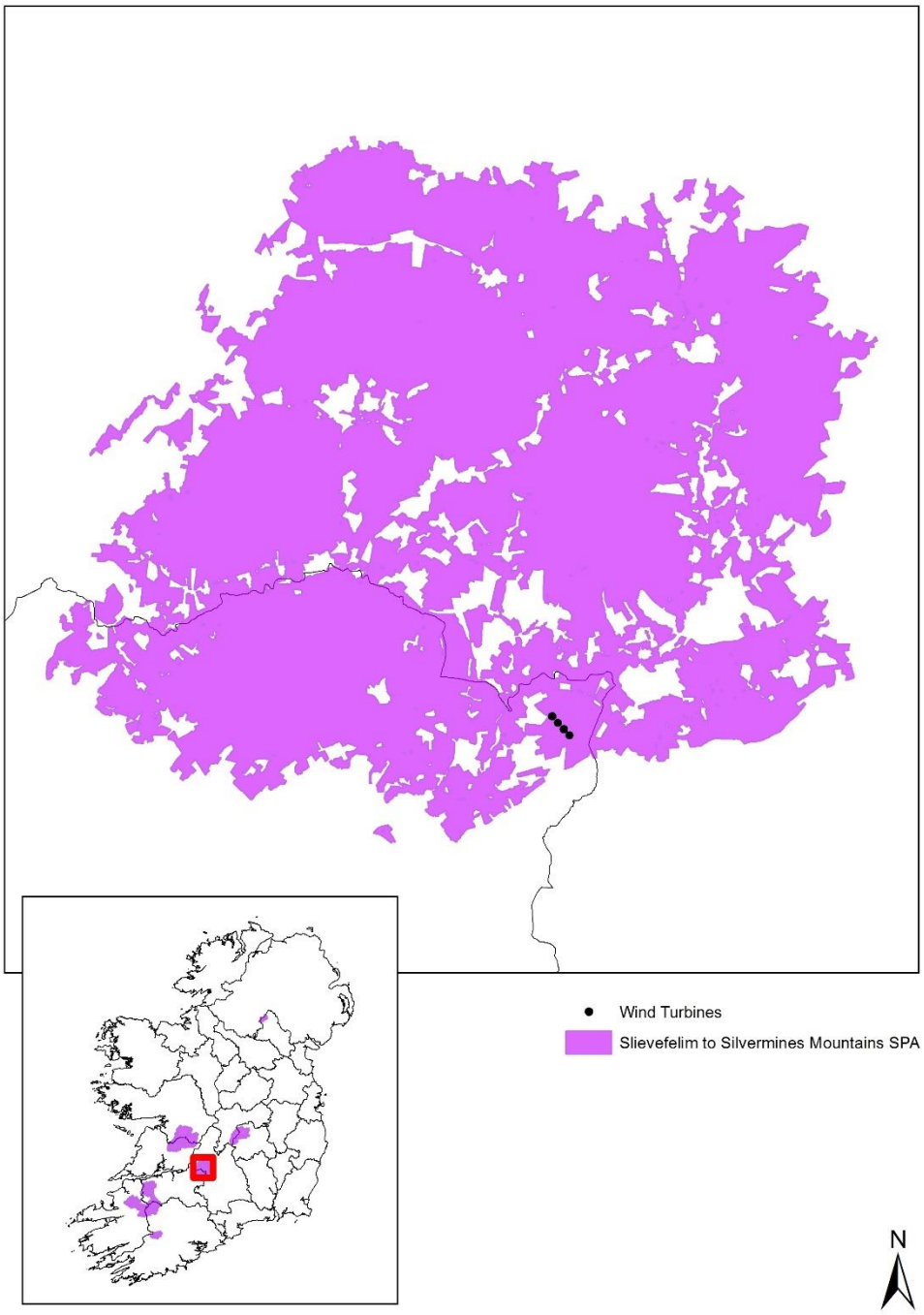
	2000	2012	2025	2035	2045
Foraging Area (ha)	5566	3119	1740	3483	5840
Nesting Area (ha)	5026	2609	1211	1579	4944
Foraging % of forest	66	28	16	31	52
Nesting % of forest	59	23	11	14	44

There are four wind turbines located within the SPA boundary and no others within 500m of the boundary (see Appendix 6d).

Pressure monitoring

Within the 10km squares near the SPA there were 17 pressures recorded by fieldworkers including A6, B1, B2, B3, B4, C1, C2, C3, D1, D3, D5, G1, G4, G5, J2, X, O. Most frequently recorded pressures were X (no pressures) and B2 (forest and plantation management & use).

Figure 6d. Spatial distribution of wind turbines within the SPA boundary and <500m from the SPA boundary. Locations of turbines derived from 2013 orthophotography (NPWS, unpublished data).



Appendix 7. Slieve Aughty Mountains SPA

Site code: 004168

Location: Co. Clare & Co. Galway

Area: 59,435.65ha

Breeding parameters

In 2015 this SPA held 8-14 breeding pairs of hen harrier. This equates to 8.9% of the national population and 20.3% of the SPA network population.

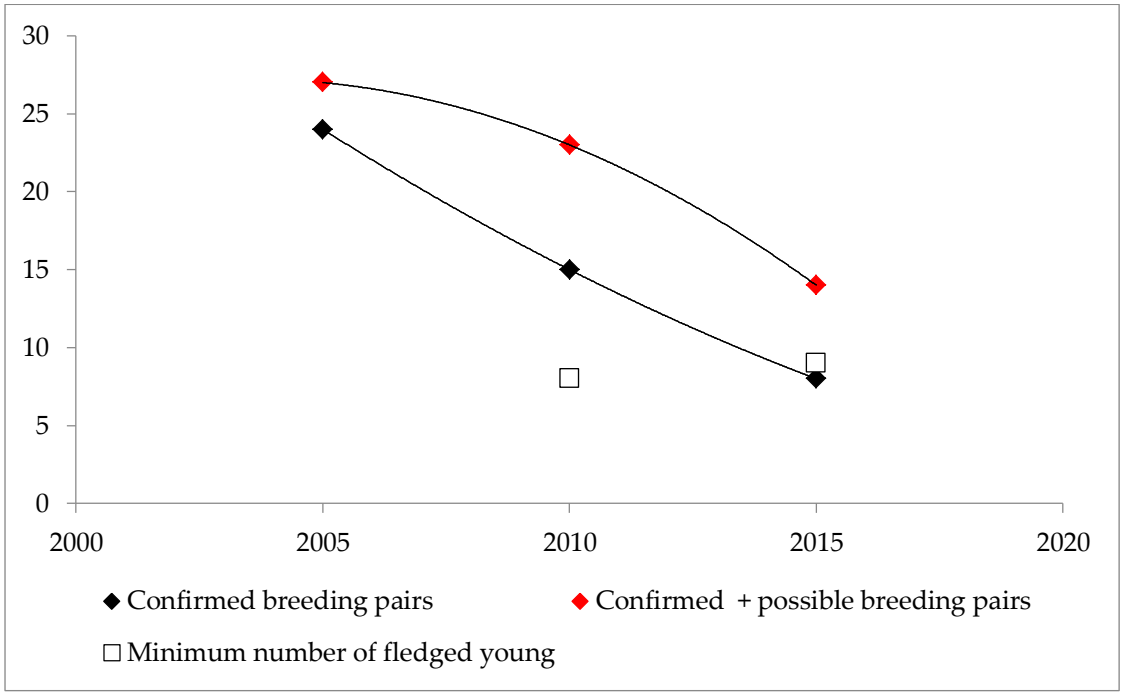
The number of pairs classed as confirmed breeders as a proportion of the site's breeding population equates to 57% which is lower than both the national proportion (69%) and the total SPA proportion (74%).

Breeding success of confirmed pairs in 2015 was estimated to be 50%, which is higher than the national estimate (at 45%) and the same as the estimated rate for the total SPA population (at 49%).

Breeding productivity was estimated at 2.3 fledged young per successful pair. This is higher than both the national estimate (at 2.1 young) and the total SPA population (at 2.2 young).

This SPA produced 9 fledged young in 2015. This equates to 8.8% of the total minimum number of fledged birds in Ireland and represents 16.1% of the total SPA population of fledged birds.

Figure 7a. Breeding parameters recorded over recent surveys for the Slieve Aughty Mountains SPA.



Population in 2005	Population in 2010	Population in 2015	% change in total population since 2005
24-27 pairs	15-23 pairs	8-14 pairs	-48.1%

Habitat composition & wind turbines

This SPA (based on Moran & Wilson-Parr, 2014) has between 33.4 – 37.4% suitable nesting habitat and 50.0 – 54.0% suitable foraging habitat. There are 31,744.1ha (or 53.4% of total SPA area) in forest or woodland cover of which 5,789.5ha – 8,173.9ha (9.8 – 13.8%) are classed as suitable for nesting hen harriers.

A breakdown of foraging habitats, following Moran & Wilson-Parr (2014) is provided (Figure 7b) whilst based on an analysis contained in NPWS (2015) estimates the variant in the usefulness of the forest estate for both nesting and foraging purposes at this site over a 45 year period is shown (Figure 7c).

Figure 7b. Foraging habitat status based on Moran & Wilson-Parr (2014) and NPWS (2015).

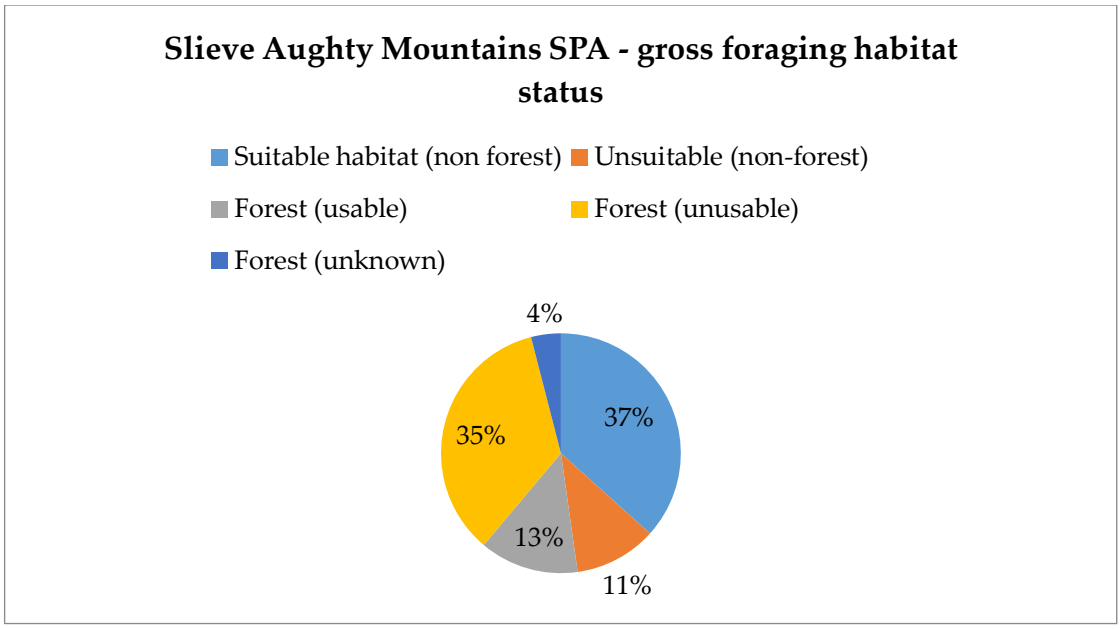
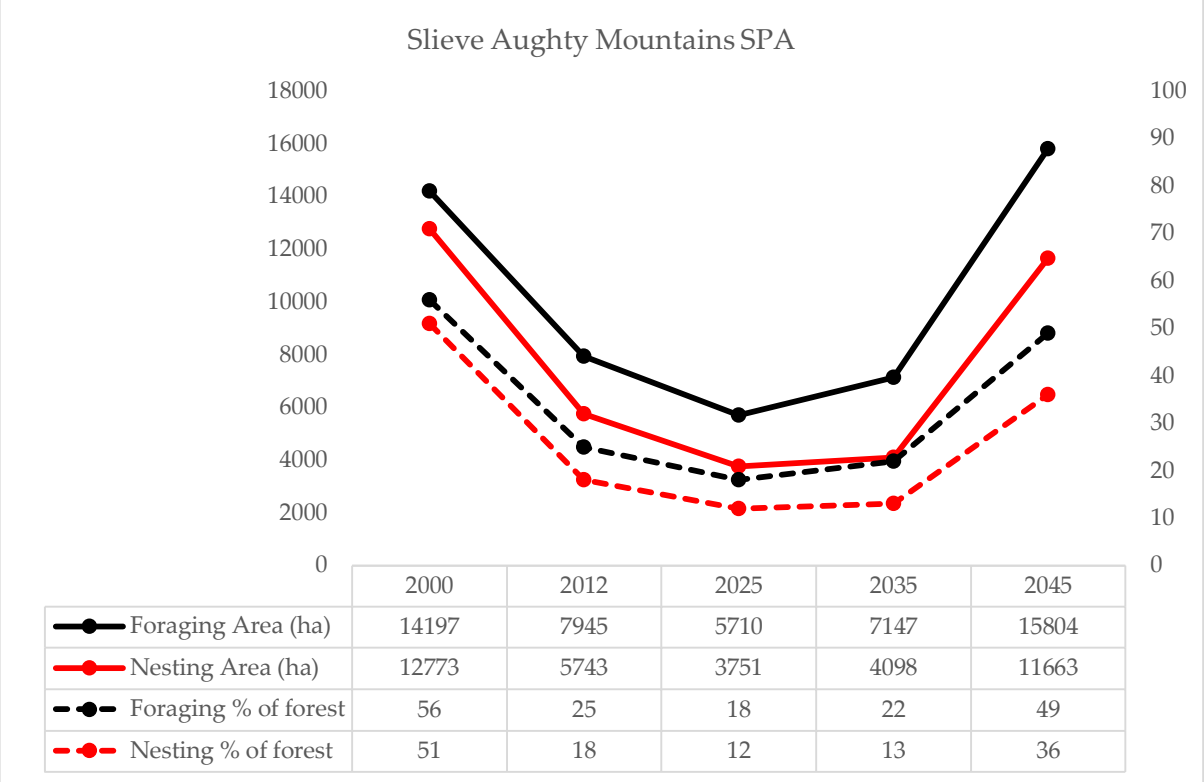


Figure 7c. Foraging and nesting habitat area and suitability based on NPWS (2015).



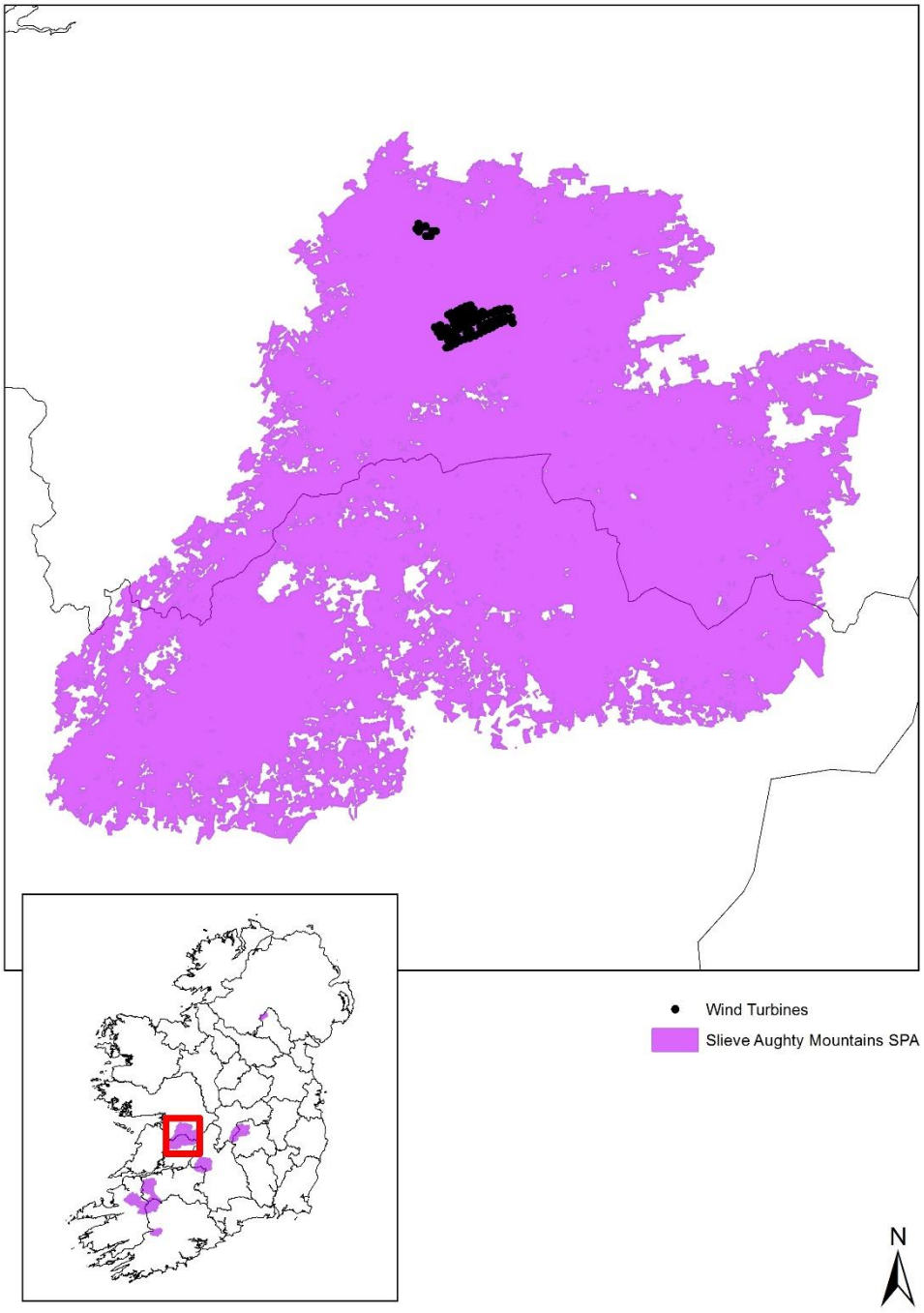
	2000	2012	2025	2035	2045
Foraging Area (ha)	14197	7945	5710	7147	15804
Nesting Area (ha)	12773	5743	3751	4098	11663
Foraging % of forest	56	25	18	22	49
Nesting % of forest	51	18	12	13	36

There are 77 wind turbines located within the SPA boundary and no others within 500m of the boundary (see Appendix 7d).

Pressure monitoring

Within the 10km squares near the SPA there were 28 pressures recorded by fieldworkers including A2, A3, A5, A8, B1, B2, B3, B4, B5, B6, C1, C2, C3, D1, D2, D3, D4, G1, G3, G4, J1, J2, J3, J4, J5, K2, X, 0. Most frequently recorded pressures were D1 (paths, tracks, cycling tracks including non-paved forest roads), J3 (uncontrolled burning), D3 (utility & service lines) and B2 (forest and plantation management & use).

Figure 7d. Spatial distribution of wind turbines within the SPA boundary and <500m from the SPA boundary. Locations of turbines derived from 2013 orthophotography (NPWS, unpublished data).



Appendix 8. Slieve Bloom Mountains SPA

Site code: 04160

Location: Co. Offaly & Co. Laois

Area: 21,761.25ha

Breeding parameters

In 2015 this SPA held 12-13 breeding pairs of hen harrier. This equates to 8.2% of the national population and 18.8% of the SPA network population.

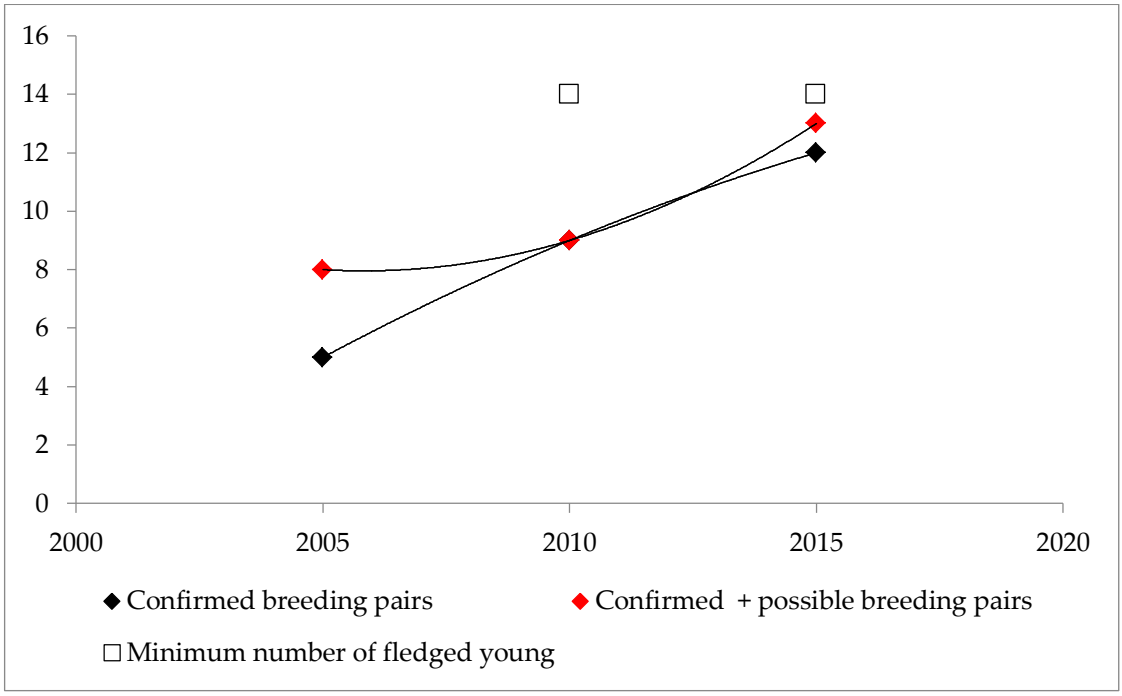
The number of pairs classed as confirmed breeders as a proportion of the site's breeding population equates to 92.3% which is higher than both the national proportion (69%) and the total SPA proportion (74%).

Breeding success of confirmed pairs in 2015 was estimated to be 53.8% which is higher than the national estimate (at 45%) and higher than the estimated rate for the total SPA population (at 49%).

Breeding productivity was estimated at 2.3 fledged young per successful pair. This is higher than both the national estimate (at 2.1 young) and the total SPA population (at 2.2 young).

This SPA produced 14 fledged young. This equates to 13.7% of the total minimum number of fledged birds in Ireland and represents 25% of the total SPA population of fledged birds.

Figure 8a. Breeding parameters recorded over recent surveys for the Slieve Bloom Mountains SPA.



Population in 2005	Population in 2010	Population in 2015	% change in total population since 2005
5-8 pairs	9 pairs	12-13 pairs	+62.5%

Habitat composition & wind turbines

This SPA (based on Moran & Wilson-Parr, 2014) has between 36.1 – 44.6% suitable nesting habitat and 47.6 – 56.2% suitable foraging habitat. There are 13,663.1ha (or 62.8% of total SPA area) in forest or woodland cover of which 2,605.7ha – 4,460.7ha (12.0 – 20.5%) are classed as suitable for nesting hen harriers.

A breakdown of foraging habitats, following Moran & Wilson-Parr (2014) is provided (Figure 8b) whilst based on an analysis contained in NPWS (2015) estimates the variant in the usefulness of the forest estate for both nesting and foraging purposes at this site over a 45 year period is shown (Figure 8c).

Figure 8b. Foraging habitat status based on Moran & Wilson-Parr (2014) and NPWS (2015).

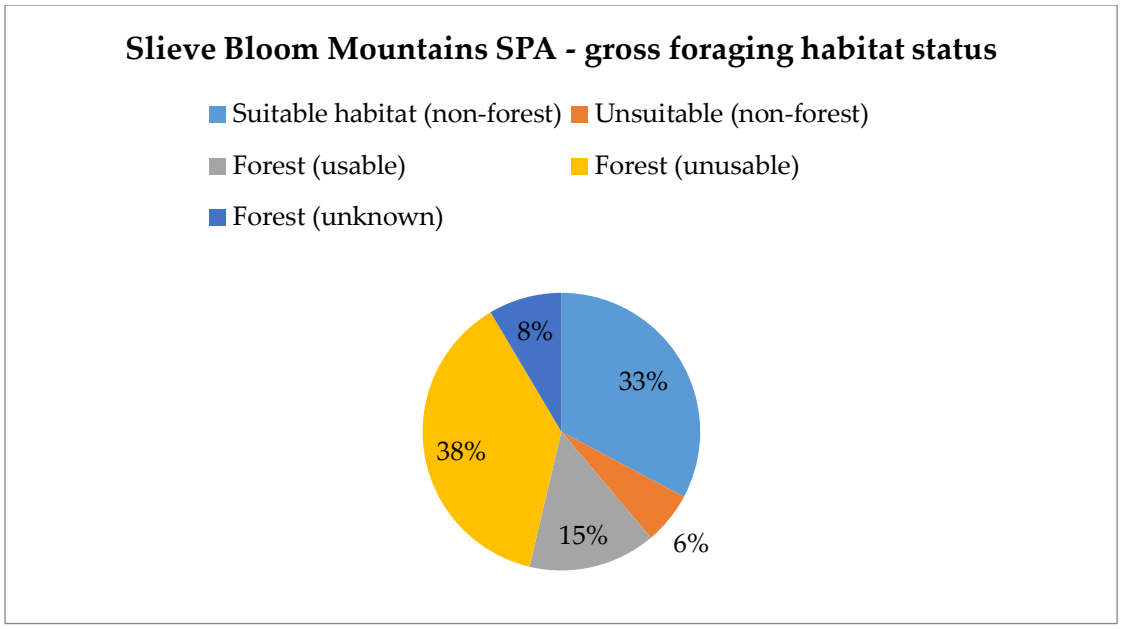
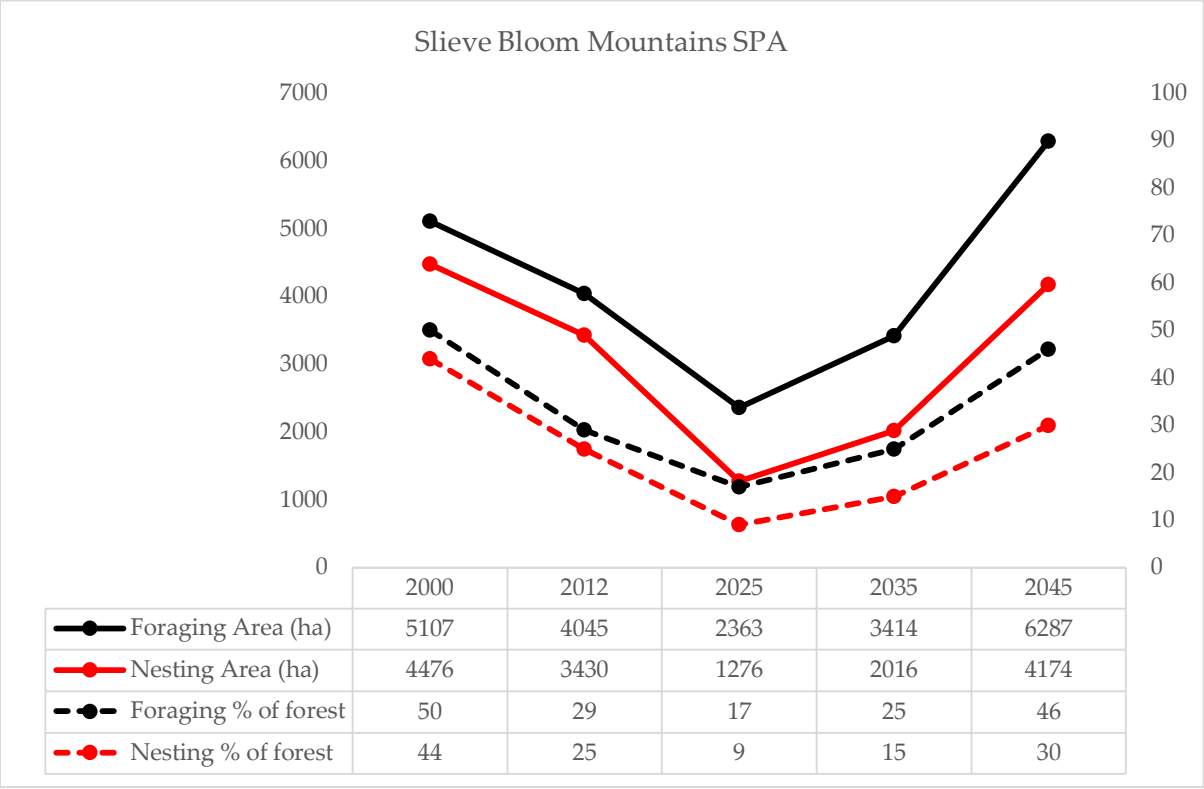


Figure 8c. Foraging and nesting habitat area and suitability based on NPWS (2015).



	2000	2012	2025	2035	2045
Foraging Area (ha)	5107	4045	2363	3414	6287
Nesting Area (ha)	4476	3430	1276	2016	4174
Foraging % of forest	50	29	17	25	46
Nesting % of forest	44	25	9	15	30

There are no wind turbines located within the SPA boundary and no others within 500m of the boundary.

Pressure monitoring

Within the 10km squares near the SPA there were 21 pressures recorded by fieldworkers including A2, A3, A5, A6, B1, B2, B3, C2, D1, D2, D3, E2, G1, G3, G4, J6, J7, K1, K2, X, O. Most frequently recorded pressures were B2 (forest and plantation management & use) and D2 (roads, motorways all paved/tarred roads), J6 (reduction of prey availability) and J7 (anthropogenic reduction of habitat connectivity (fragmentation)).

Appendix 9. Slieve Beagh SPA

Site code: 004167

Location: Co. Monaghan

Area: 3,455ha

Breeding parameters

In 2015 this SPA held three breeding pairs of hen harrier. This equates to 1.9% of the national population and 4.3% of the SPA network population.

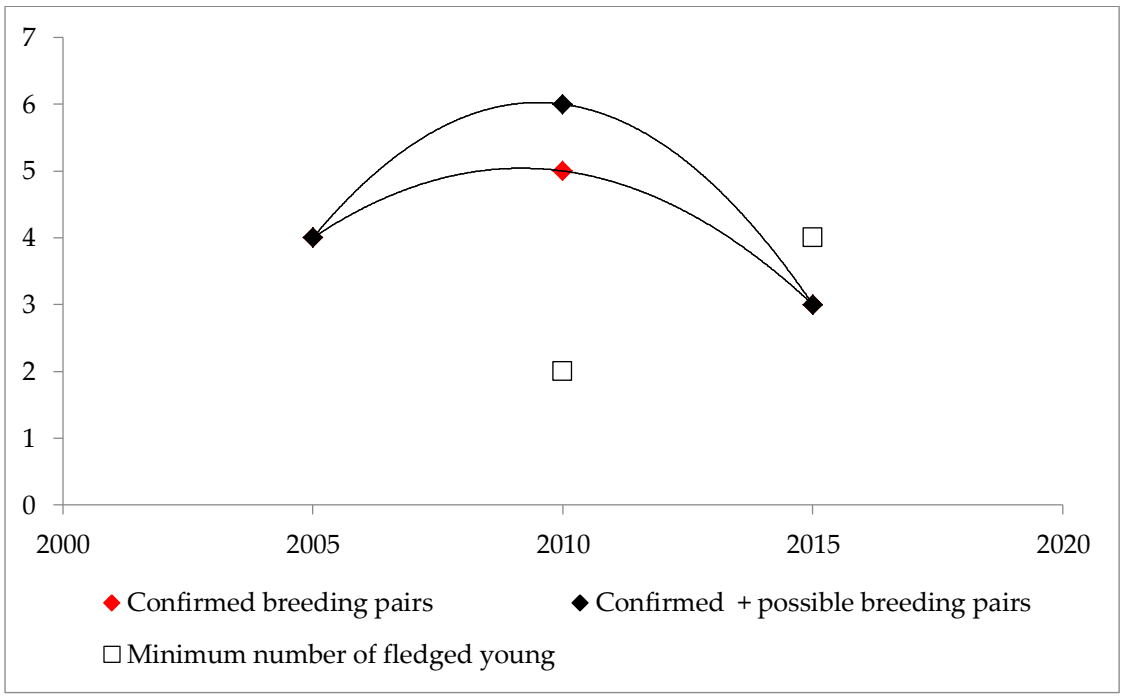
The number of pairs classed as confirmed breeders as a proportion of the site's breeding population equates to 100% (since only three pairs were located) which is higher than both the national proportion (69%) and the total SPA proportion (74%).

Breeding success was 33.3% of confirmed pairs in 2015, which is lower than both the national estimate (at 45%) and lower than the estimated rate for the total SPA population (at 49%).

Breeding productivity was estimated at 4.0 fledged young per successful pair. This is higher than both the national estimate (at 2.1 young) and the total SPA population (at 2.2 young).

This SPA produced 4 fledged young. This equates to 3.9% of the total minimum number of fledged birds in Ireland and represents 7.1% of the total SPA population of fledged birds.

Figure 9a. Breeding parameters recorded over recent surveys for the Slieve Beagh SPA.



Population in 2005	Population in 2010	Population in 2015	% change in total population since 2005
4 pairs	5-6 pairs	3 pairs	-25.0%

Habitat composition & wind turbines

This SPA (based on Moran & Wilson-Parr, 2014) has between 57.1 – 59.7% suitable nesting habitat and 69.8 – 72.5% suitable foraging habitat. There are 1,549.3ha (or 44.9% of total SPA area) in forest or woodland cover of which 587.8ha – 678.8ha (17.0 – 19.7%) are classed as suitable for nesting hen harriers.

A breakdown of foraging habitats, following Moran & Wilson-Parr (2014) is provided (Figure 9b) whilst based on an analysis contained in NPWS (2015) estimates the variant in the usefulness of the forest estate for both nesting and foraging purposes at this site over a 45 year period is shown (Figure 9c).

Figure 8b. Foraging habitat status based on Moran & Wilson-Parr (2014) and NPWS (2015).

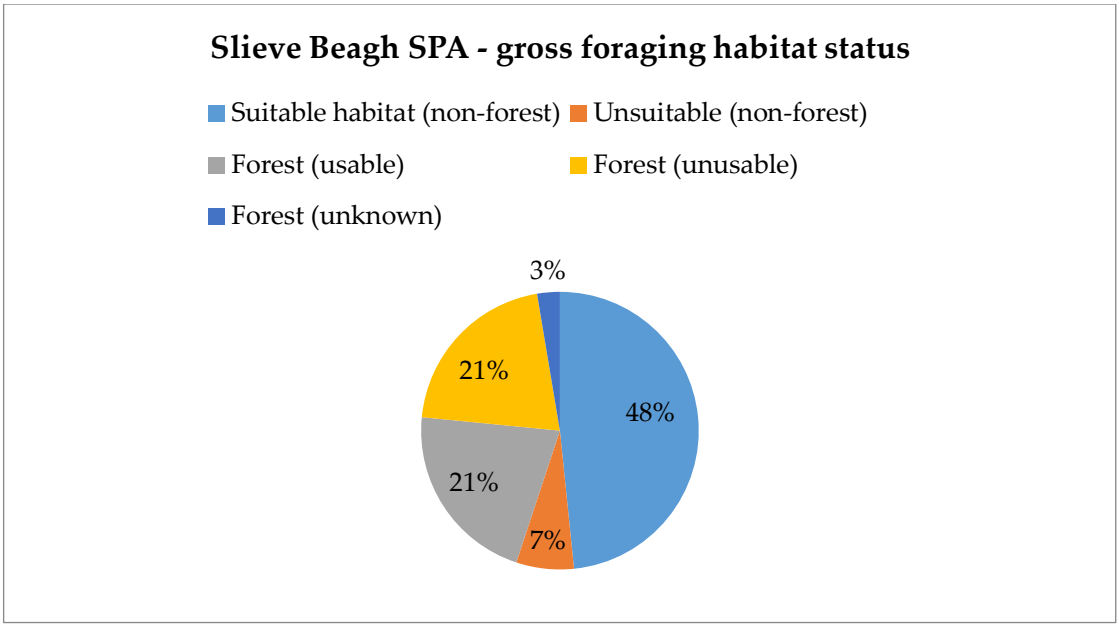
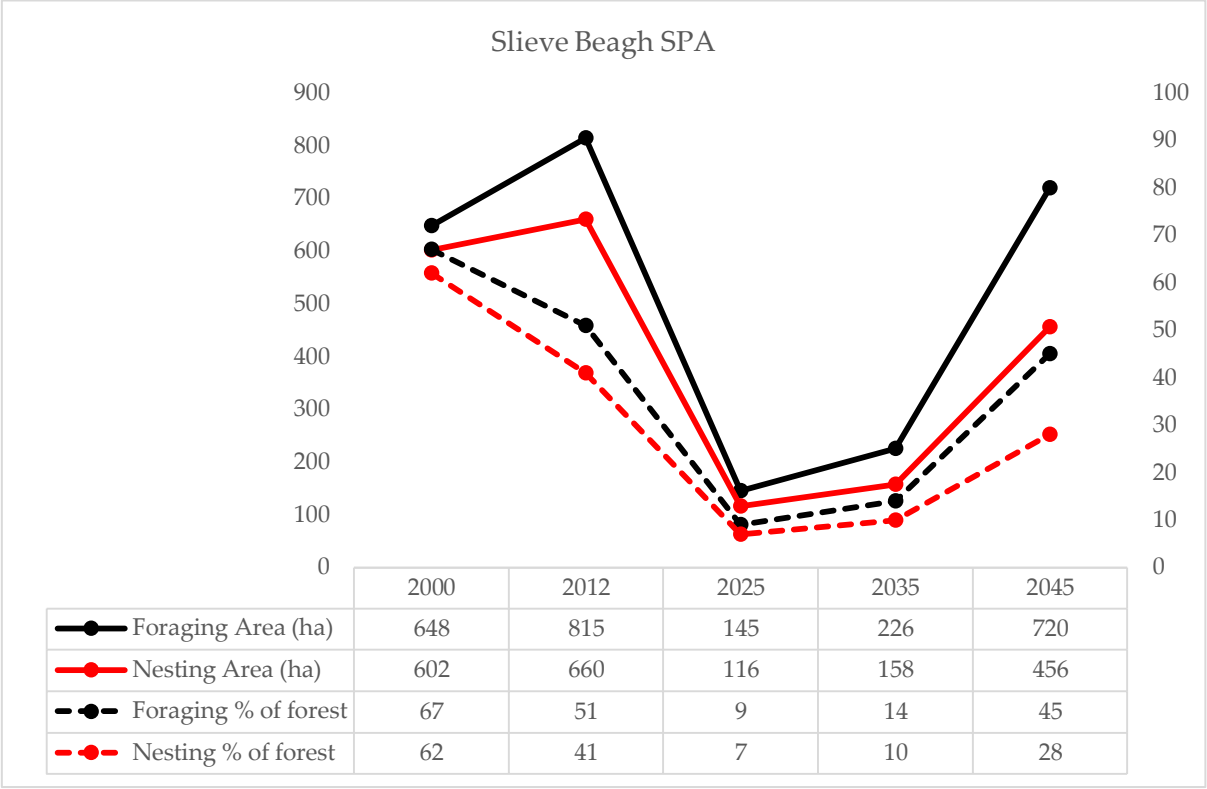


Figure 8c. Foraging and nesting habitat area and suitability based on NPWS (2015).



	2000	2012	2025	2035	2045
Foraging Area (ha)	648	815	145	226	720
Nesting Area (ha)	602	660	116	158	456
Foraging % of forest	67	51	9	14	45
Nesting % of forest	62	41	7	10	28

There are no wind turbines located within the SPA boundary and no others within 500m of the boundary.

Pressure monitoring

Within the 10km squares near the SPA there were 11 pressures recorded by fieldworkers including A5, B2, B4, C1, C2, D2, J3, J6, K1, K2, O. Most frequently recorded pressures were C2 (mechanical removal of peat); C1 (hand cutting of peat), J3 (uncontrolled burning) and O (cattle trampling & forest maturation).

Appendix 10. The numbers of each pressure codes recorded and total number of pressure records (Pressure Index 1) and standardised (Pressure Index 2 = total number of pressures / total number of visits to square) within 500m and 2km of hen harrier territories and/or suitable hen harrier breeding habitats within SPAs

	Number of detections within 500m								**Number of detections within 2km**						
Pressure Code	SPA - 4162	SPA - 4168	SPA - 4167	SPA - 4160	SPA - 4165	SPA - 4161	Total		SPA - 4162	SPA - 4168	SPA - 4167	SPA - 4160	SPA - 4165	SPA - 4161	Total
A1	0	0	0	0	0	0	0		0	0	0	0	0	0	0
A2	5	0	0	1	0	27	33		20	2	0	0	0	27	49
A3	0	3	0	2	0	0	5		0	0	0	1	0	0	1
A4	1	0	0	0	0	9	10		0	0	0	0	0	9	9
A5	17	1	3	1	0	0	22		12	1	2	1	0	0	16
A6	3	0	0	1	12	2	18		9	0	0	0	11	1	21
A7	0	0	0	0	0	33	33		0	0	0	0	0	33	33
A8	0	2	0	0	0	2	4		1	0	0	0	0	2	3
A9	0	0	0	0	0	34	34		0	0	0	0	0	34	34
B1	3	0	0	1	12	33	49		0	5	0	1	11	33	50
B2	27	40	6	9	17	48	147		33	44	0	7	42	45	171
B3	4	8	0	1	9	33	55		0	17	0	0	3	34	54

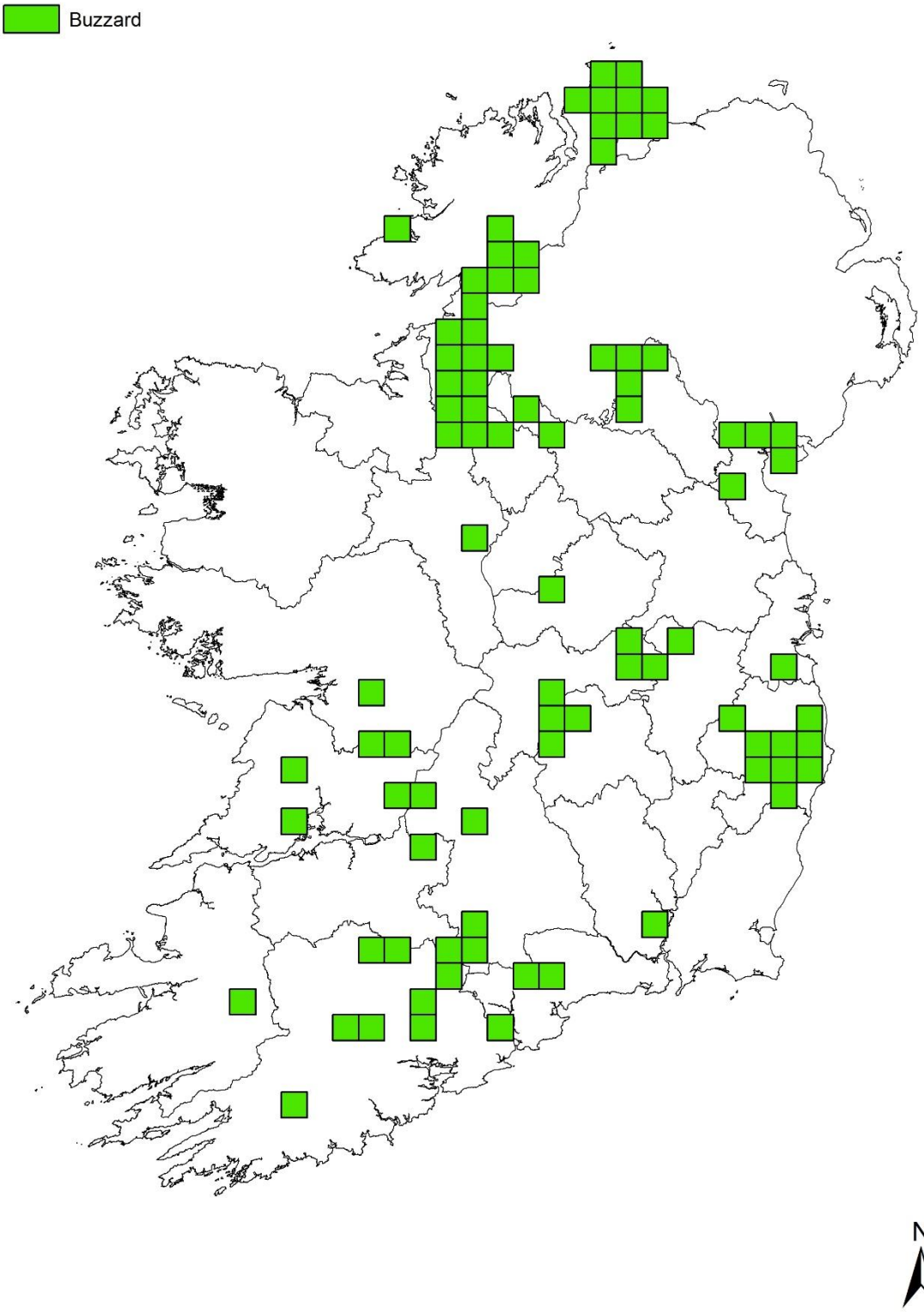
	Number of detections within 500m								**Number of detections within 2km**						
Pressure Code	SPA - 4162	SPA - 4168	SPA - 4167	SPA - 4160	SPA - 4165	SPA - 4161	Total		SPA - 4162	SPA - 4168	SPA - 4167	SPA - 4160	SPA - 4165	SPA - 4161	Total
B4	0	5	0	0	0	3	8		0	60	1	0	33	9	103
B5	0	5	0	0	0	0	5		0	3	0	0	0	0	3
B6	0	2	0	0	0	0	2		0	0	0	0	0	0	0
B7	4	0	0	0	0	0	4		0	0	0	0	0	0	0
C1	0	0	5	0	13	9	27		0	27	7	0	0	0	34
C2	0	26	17	0	18	18	79		0	29	18	1	13	6	67
C3	4	11	0	0	10	42	67		31	11	0	0	8	55	105
D1	4	99	0	5	29	29	166		0	50	0	3	25	36	114
D2	4	42	1	6	0	9	62		8	37	0	9	0	7	61
D3	4	42	0	1	4	36	87		4	49	0	0	0	36	89
D4	0	0	0	0	0	0	0		0	3	0	0	0	0	3
D5	0	0	0	0	4	0	4		4	0	0	0	0	0	4
E1	4	0	0	0	0	0	4		8	0	0	0	0	0	8
E2	0	0	0	0	0	1	1		0	0	0	2	0	0	2
F1	0	0	0	0	0	24	24		0	0	0	0	0	24	24
F2	0	0	0	0	0	0	0		0	0	0	0	0	0	0
G1	0	3	0	1	12	25	41		0	0	0	0	0	24	24
G2	0	0	0	0	0	0	0		0	0	0	0	0	0	0
G3	0	2	0	1	0	0	3		0	0	0	1	0	0	1

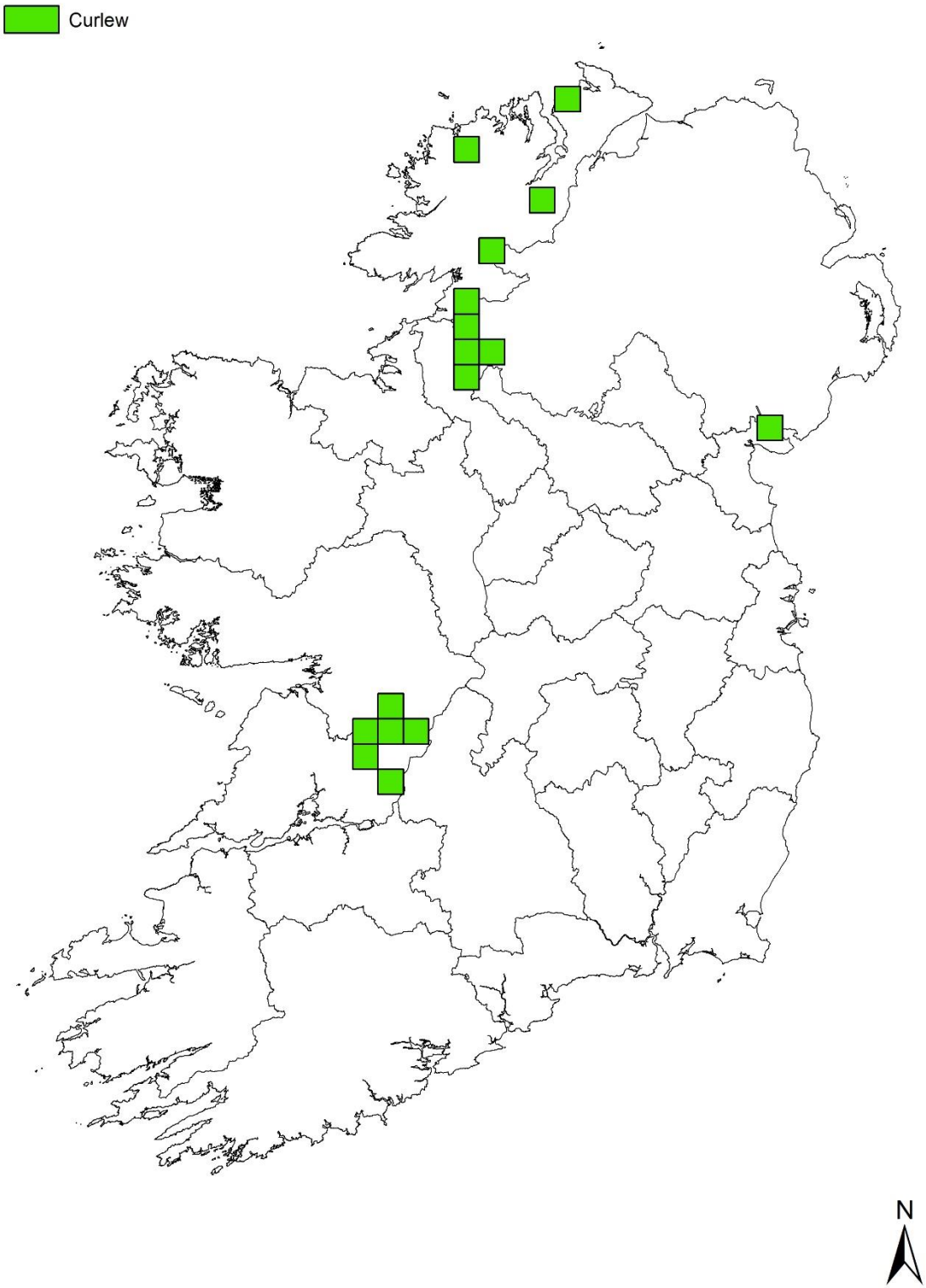
	Number of detections within 500m								**Number of detections within 2km**						
Pressure Code	SPA - 4162	SPA - 4168	SPA - 4167	SPA - 4160	SPA - 4165	SPA - 4161	Total		SPA - 4162	SPA - 4168	SPA - 4167	SPA - 4160	SPA - 4165	SPA - 4161	Total
G4	0	0	0	4	16	3	23		4	4	0	0	5	0	13
G5	0	0	0	0	5	5	10		0	0	0	0	0	0	0
G6	0	0	0	0	0	0	0		0	0	0	0	0	0	0
G7	0	0	0	0	0	0	0		0	0	0	0	0	0	0
H1	0	0	0	0	0	0	0		0	0	0	0	0	0	0
J1	0	0	0	0	0	0	0		0	5	0	0	0	0	5
J2	0	0	0	0	4	33	37		0	3	0	0	0	33	36
J3	2	30	3	0	0	36	71		2	67	9	0	0	34	112
J4	0	1	0	0	0	0	1		0	1	0	0	0	0	1
J5	0	14	0	0	0	33	47		0	14	0	0	0	33	47
J6	0	0	0	9	0	0	9		0	0	6	0	0	0	6
J7	4	0	0	0	0	33	37		4	0	0	9	0	33	46
K1	0	0	3	1	0	34	38		0	0	3	1	0	34	38
K2	0	1	2	7	0	39	49		0	22	0	0	0	36	58
X	4	27	0	5	62	14	112		0	22	0	0	72	7	101
O	0	2	6	2	4	1	15		0	1	6	0	0	0	7
Pressure Index 1	94	366	46	58	231	648	1443		140	477	52	36	223	625	1553
Pressure Index 2	16.8	11.1	1.9	1.7	14.8	30.5	76.7		20.9	12.3	2.9	1.2	15.8	31.3	84.4

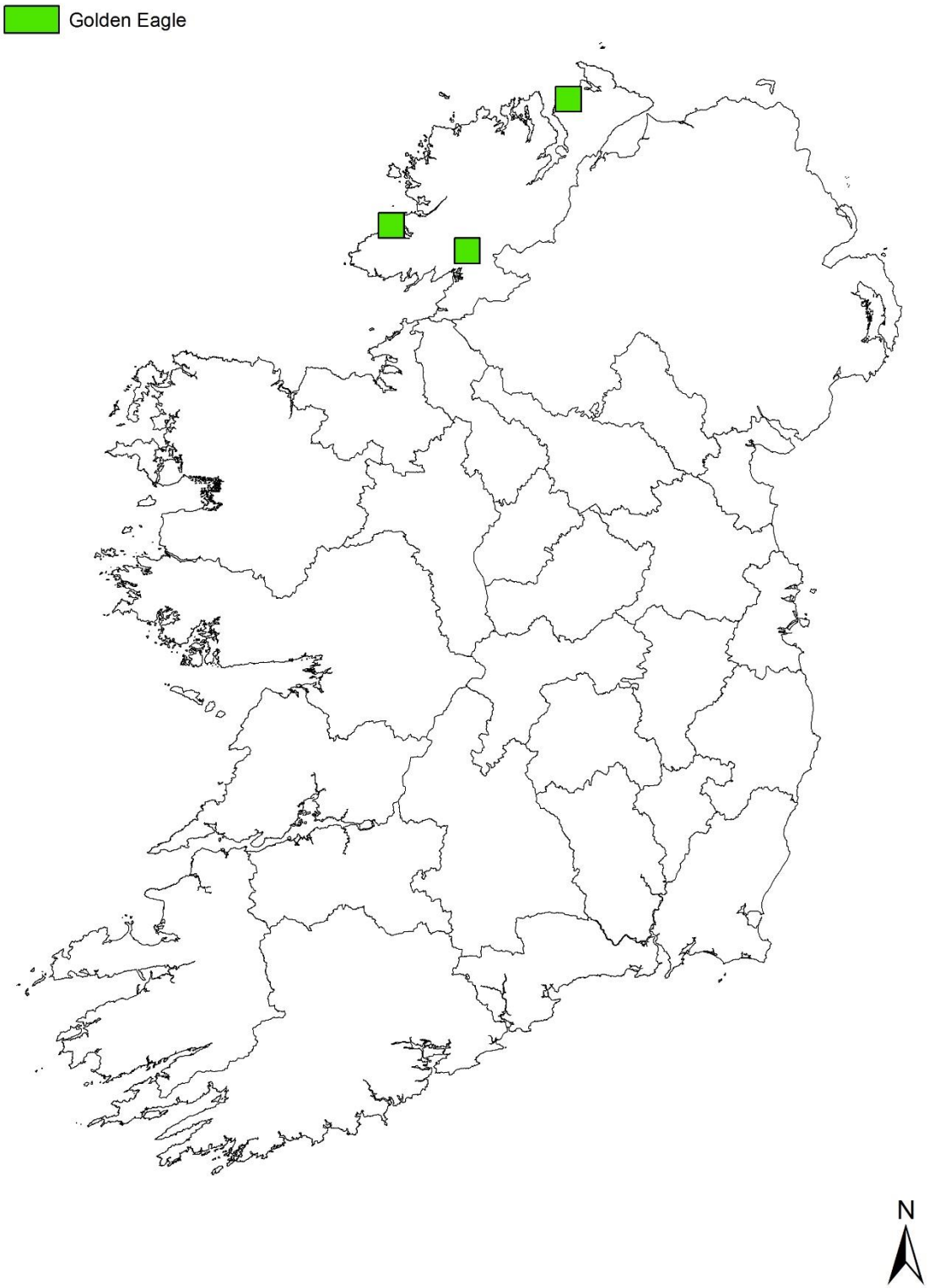
Appendix 11. The population projection model displaying predictions for inside and outside the SPAs and nationally

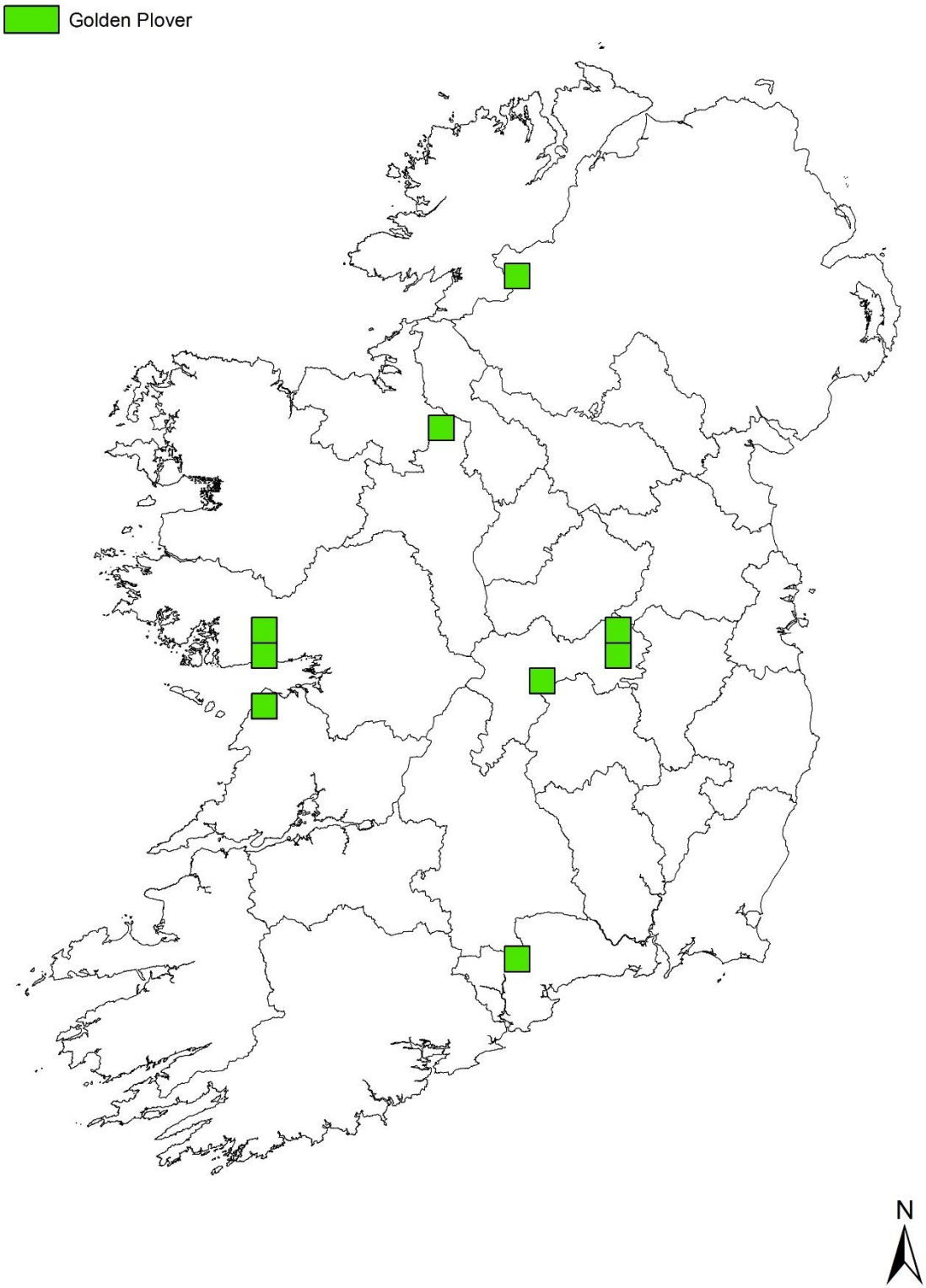
Region	Year	Confirmed pairs	Possible pairs	Total adults	Adult survival	Live adults	Dead adults	Mean young/ breeding pair	Juveniles fledged	Survival rate	Surviving young	Surplus / Deficit
Stack's to Mullaghareirk Mountain, West Limerick Hills & Mount Eagle	2015	23	5	56	0.778	43.568	12.432	0.86	24	0.361	8.664	-3.77
Mullaghanish to Musheramore Mountains	2015	1	0	2	0.778	1.556	0.444	2.00	2	0.361	0.722	0.28
Slievefelim to Silvermines Mountains	2015	4	6	20	0.778	15.56	4.44	0.3	3	0.361	1.083	-3.36
Slieve Bloom Mountains	2015	12	1	26	0.778	20.228	5.772	1.16	14	0.361	5.054	-0.72
Slieve Aughty Mountains	2015	8	6	28	0.778	21.784	6.216	0.64	9	0.361	3.249	-2.97
Slieve Beagh	2015	3	0	6	0.778	4.668	1.332	1.33	4	0.361	1.444	0.11
Inside SPAs	2015	51	18	138	0.778	107.364	30.636	0.81	56	0.361	20.216	-10.42
Outside SPAs	2015	57	31	176	0.778	136.928	39.072	0.52	46	0.361	16.606	-22.47
Whole population	2015	108	49	314	0.778	244.292	69.708	0.65	102	0.361	36.822	-32.89

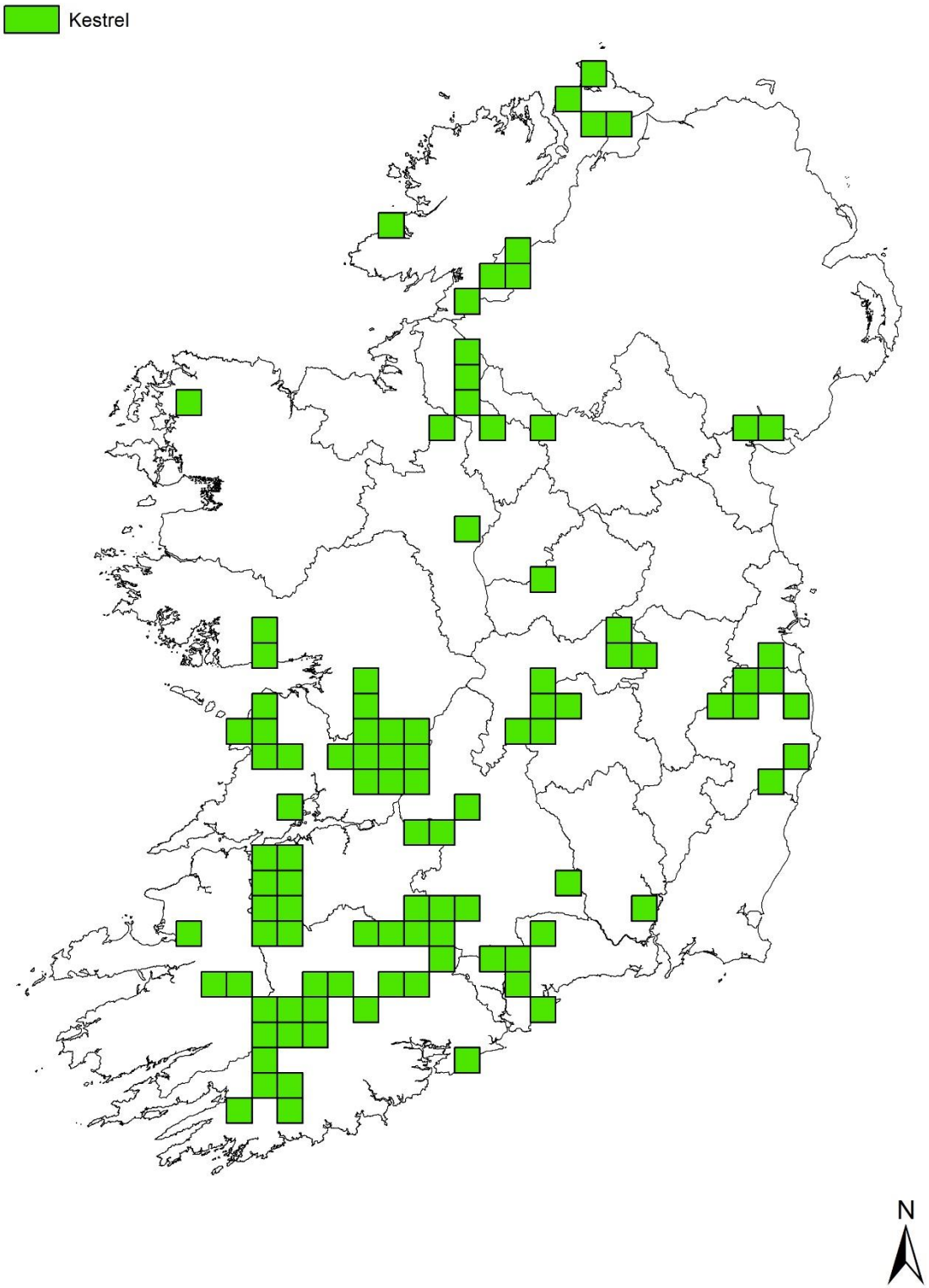
Appendix 12. Records collated in 2015 from other species showing distribution maps plotted at 10km square resolution

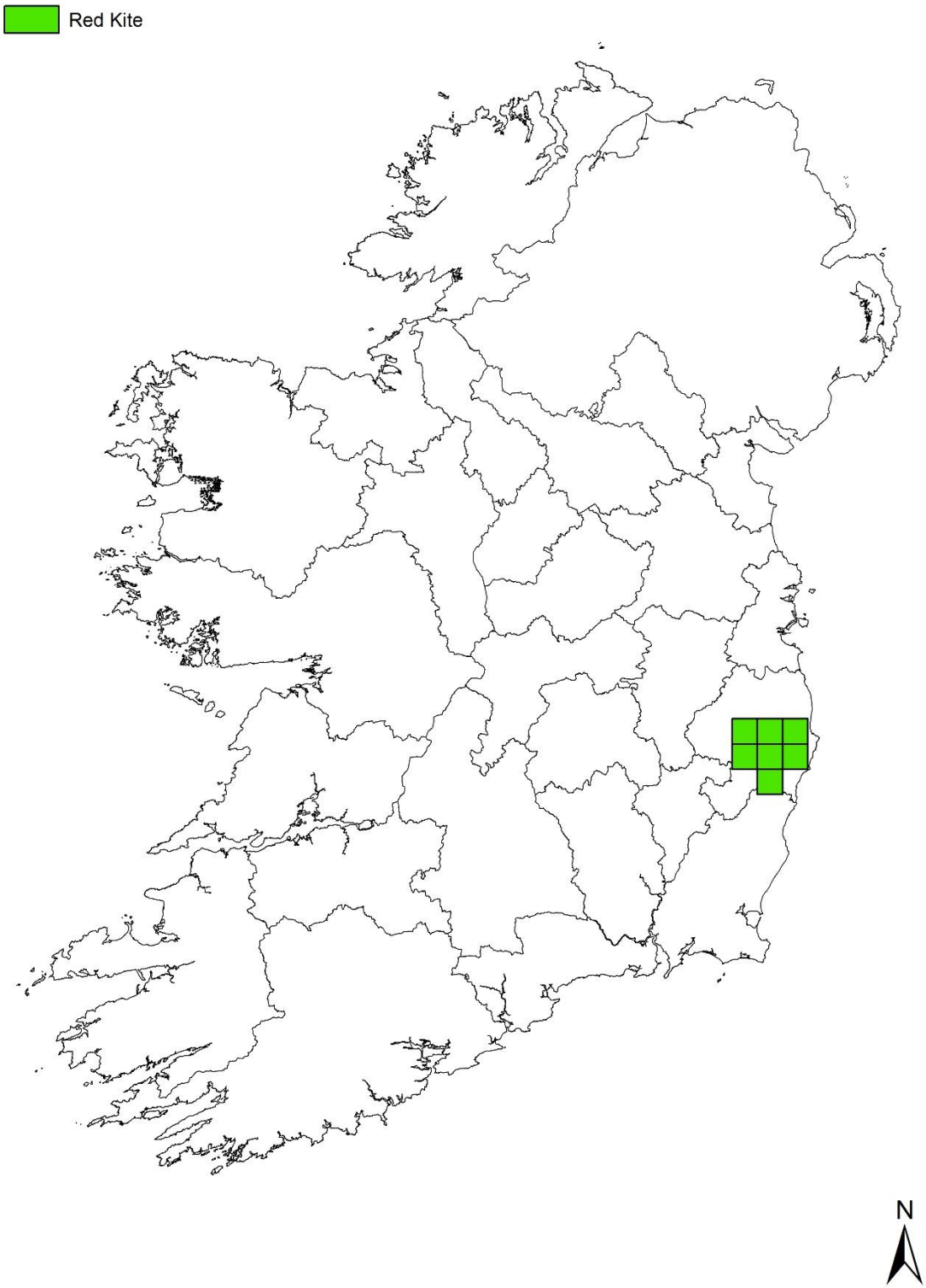


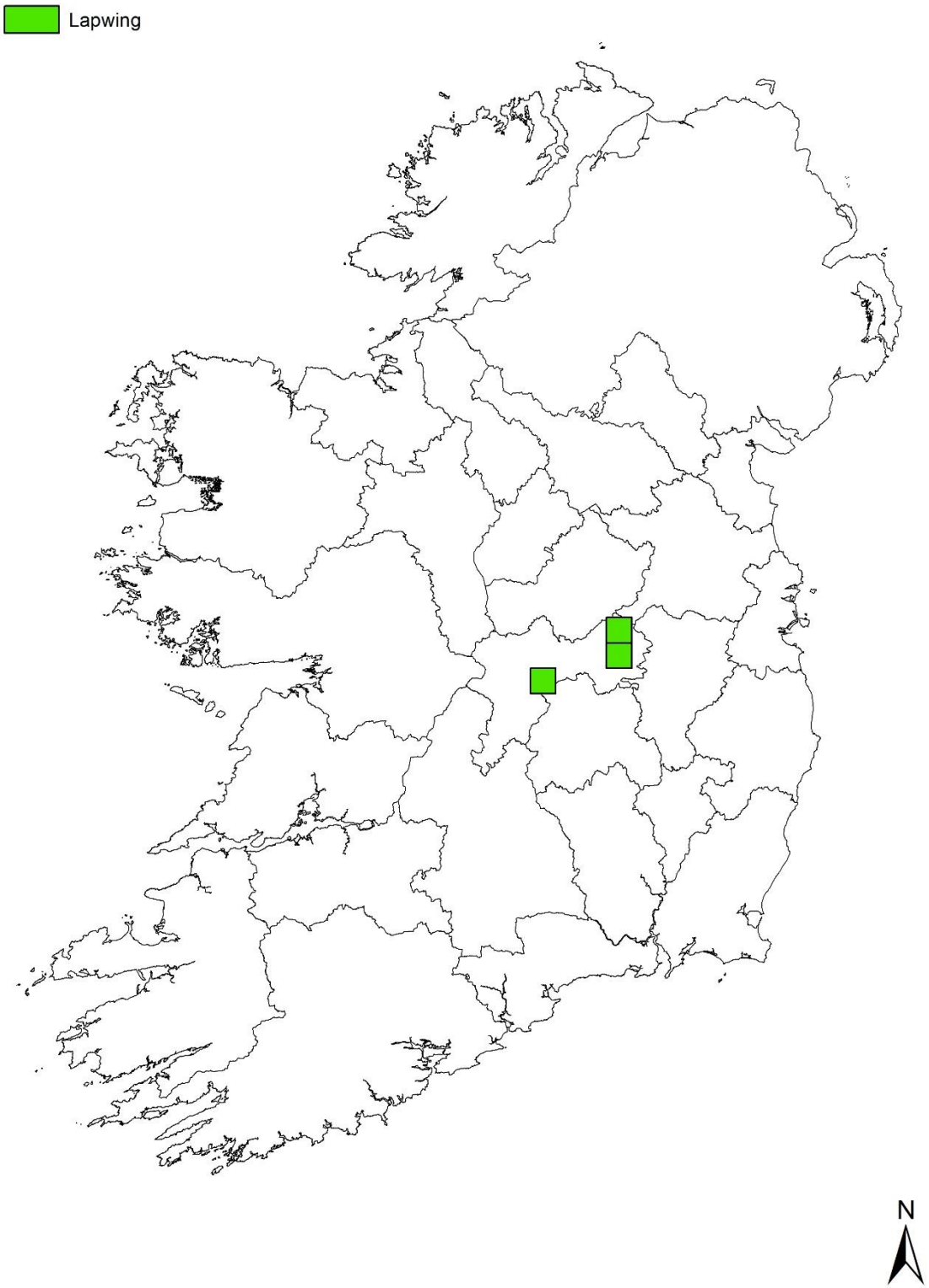

Curlew
N

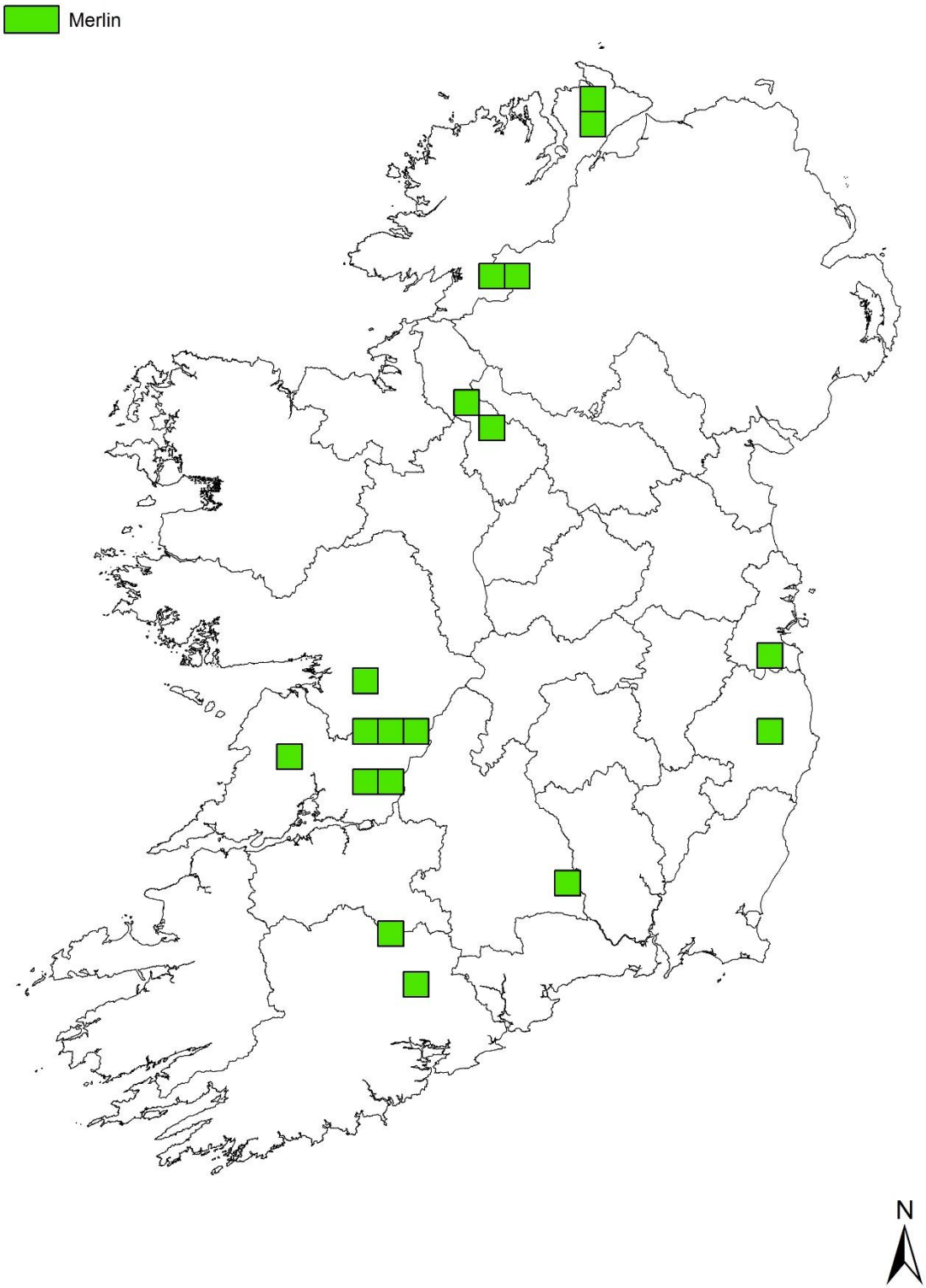

Golden Eagle
N


Golden Plover
N


Kestrel
N


Red Kite
N


Lapwing
N


Merlin
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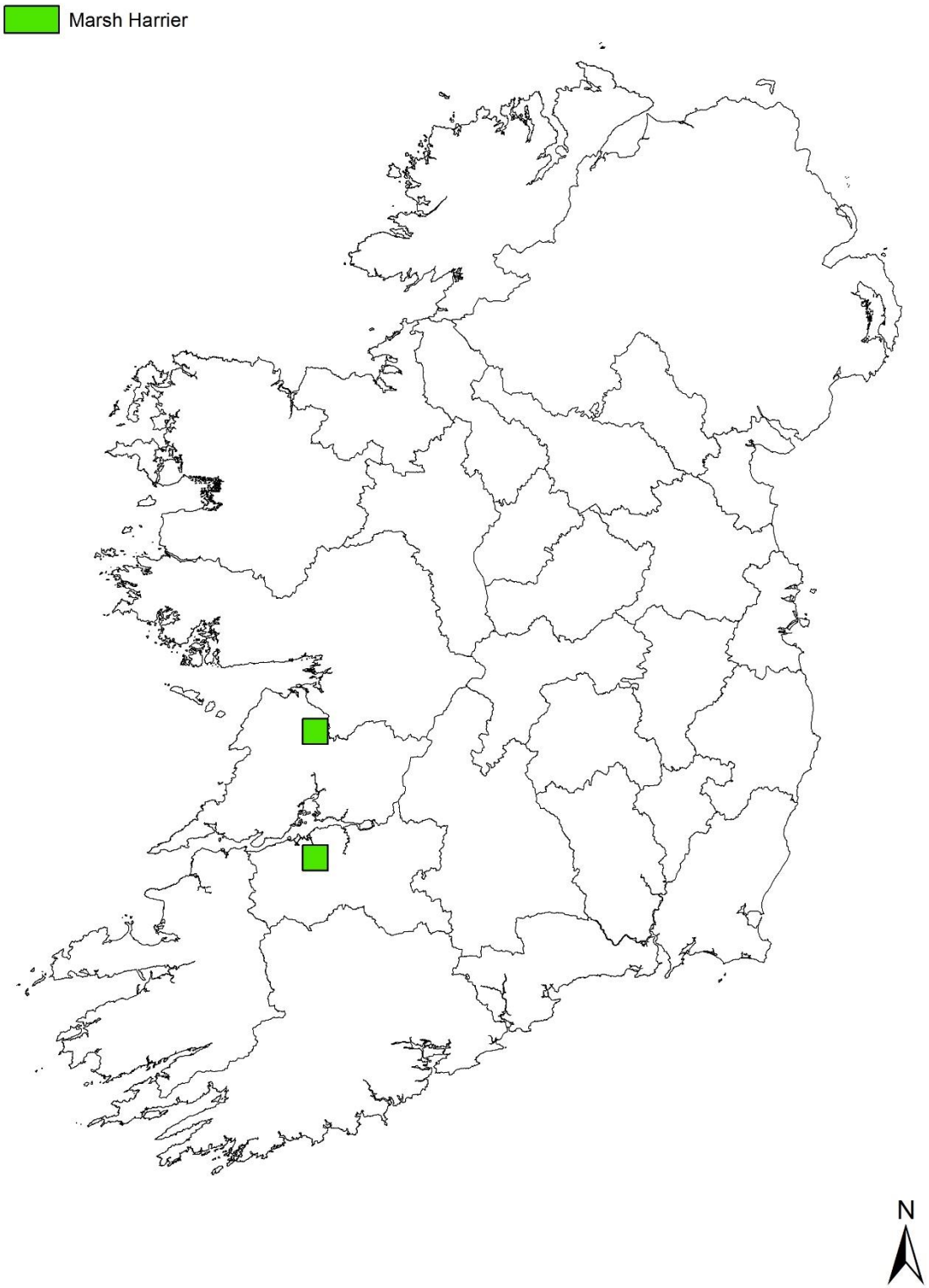
Marsh Harrier
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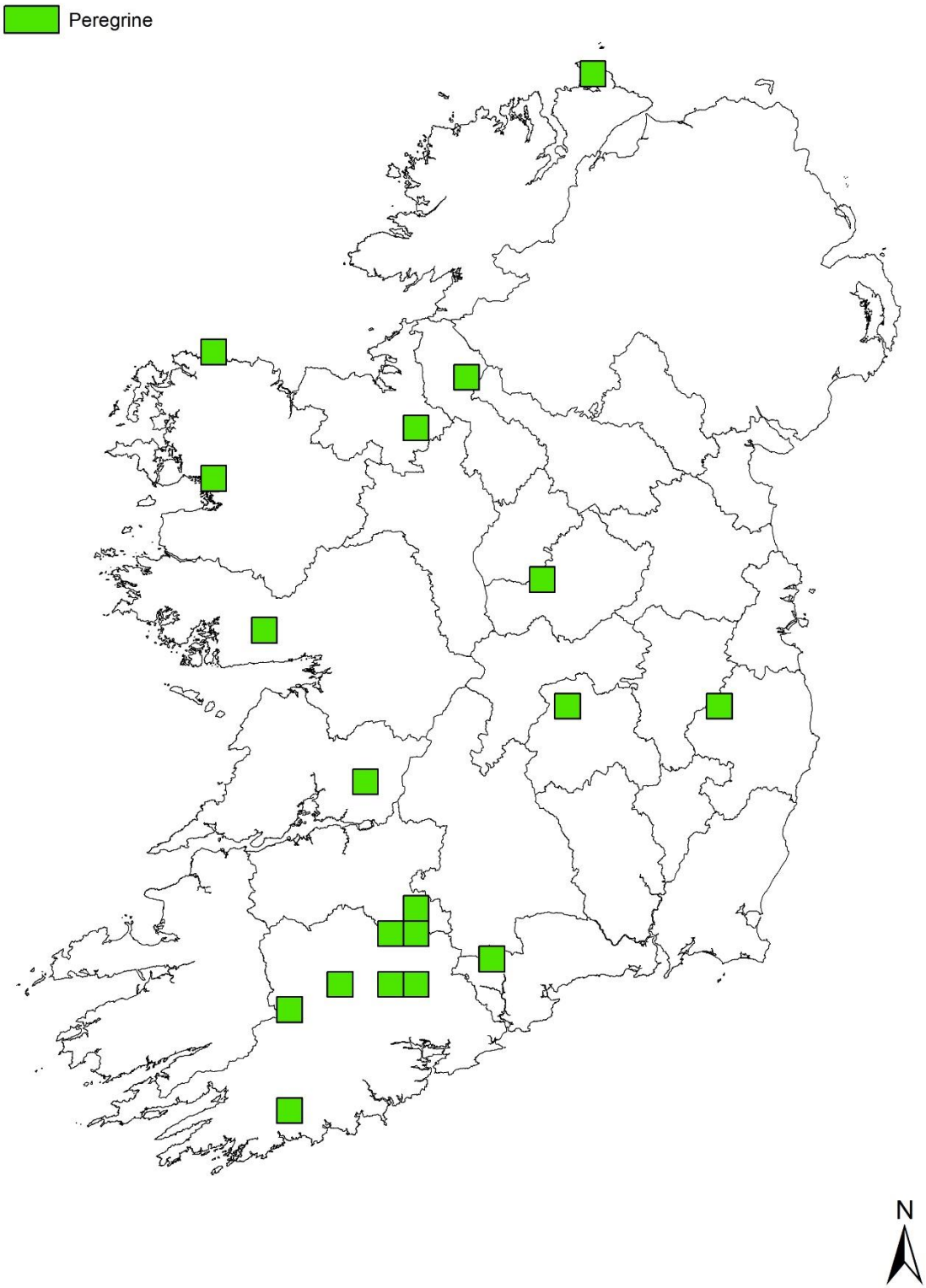
Peregrine
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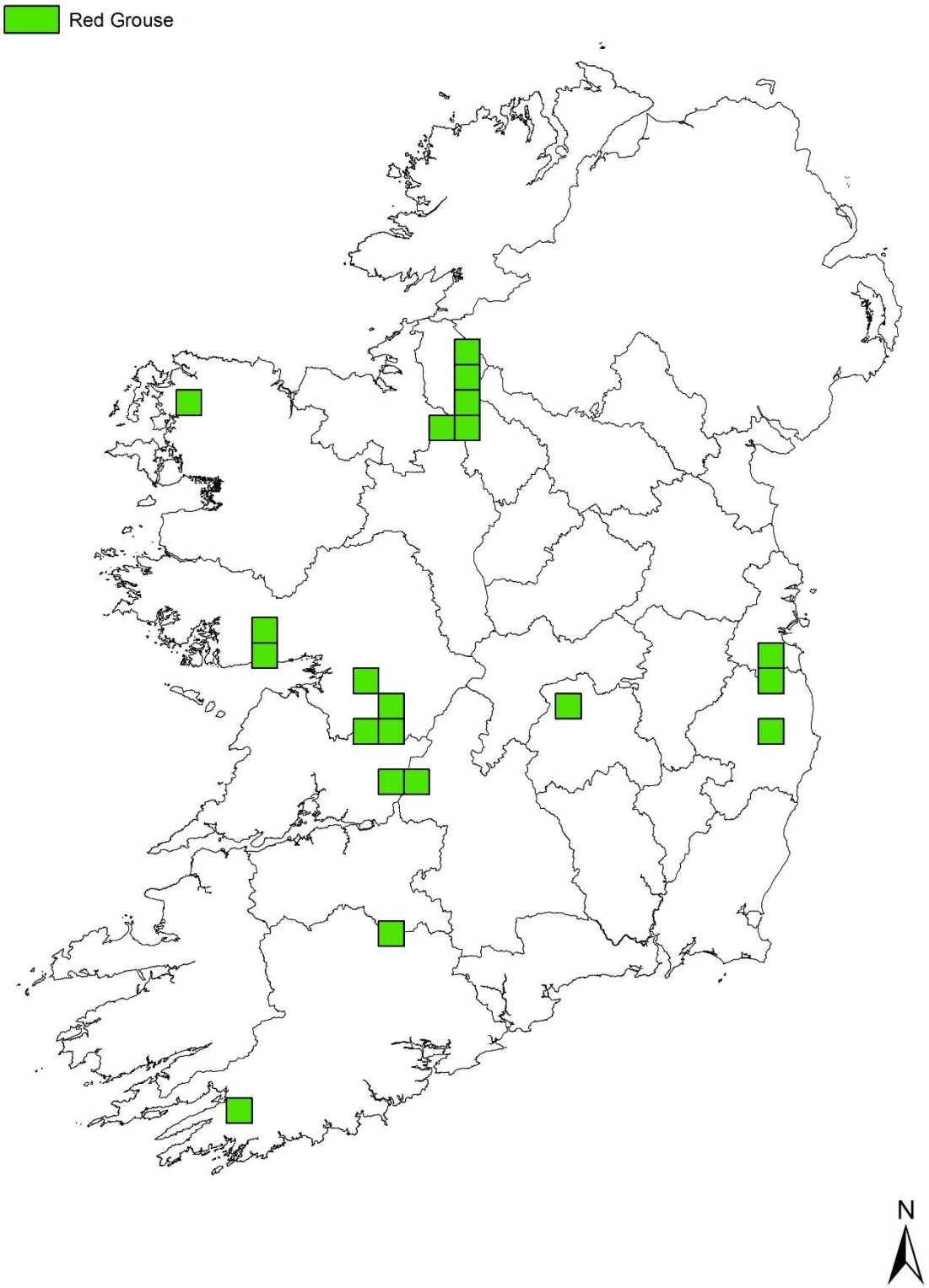
Red Grouse
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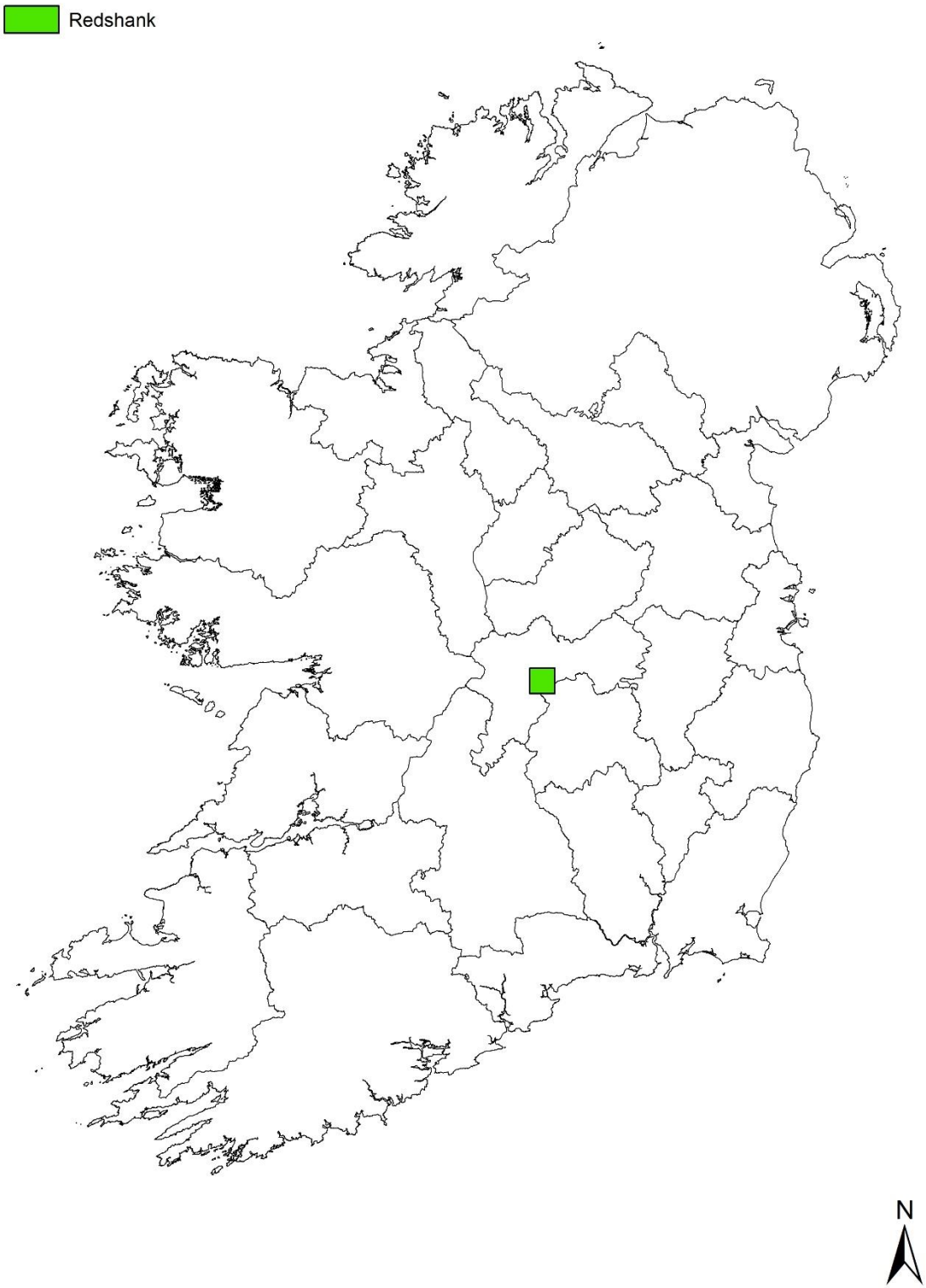
Redshank
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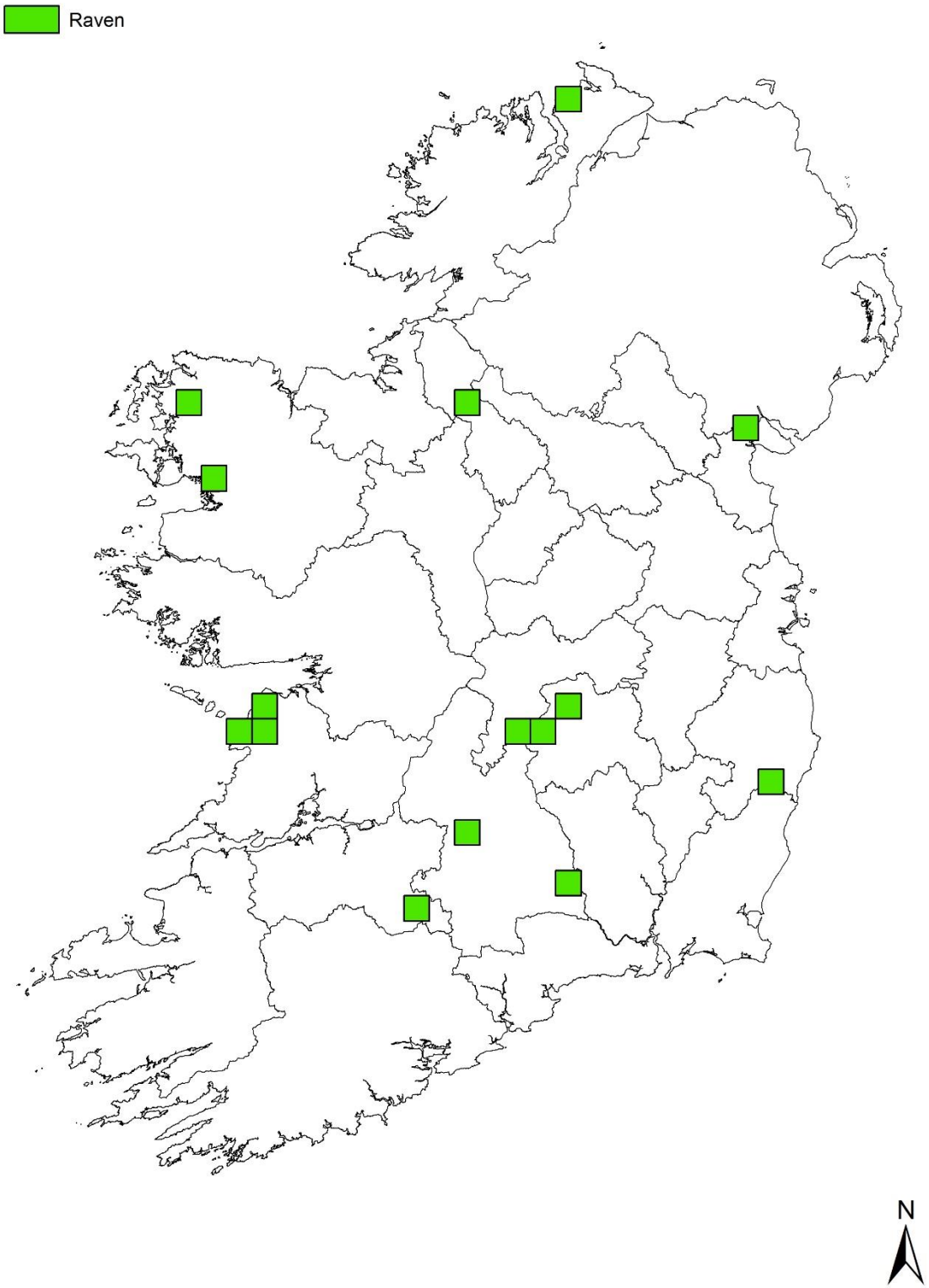
Raven
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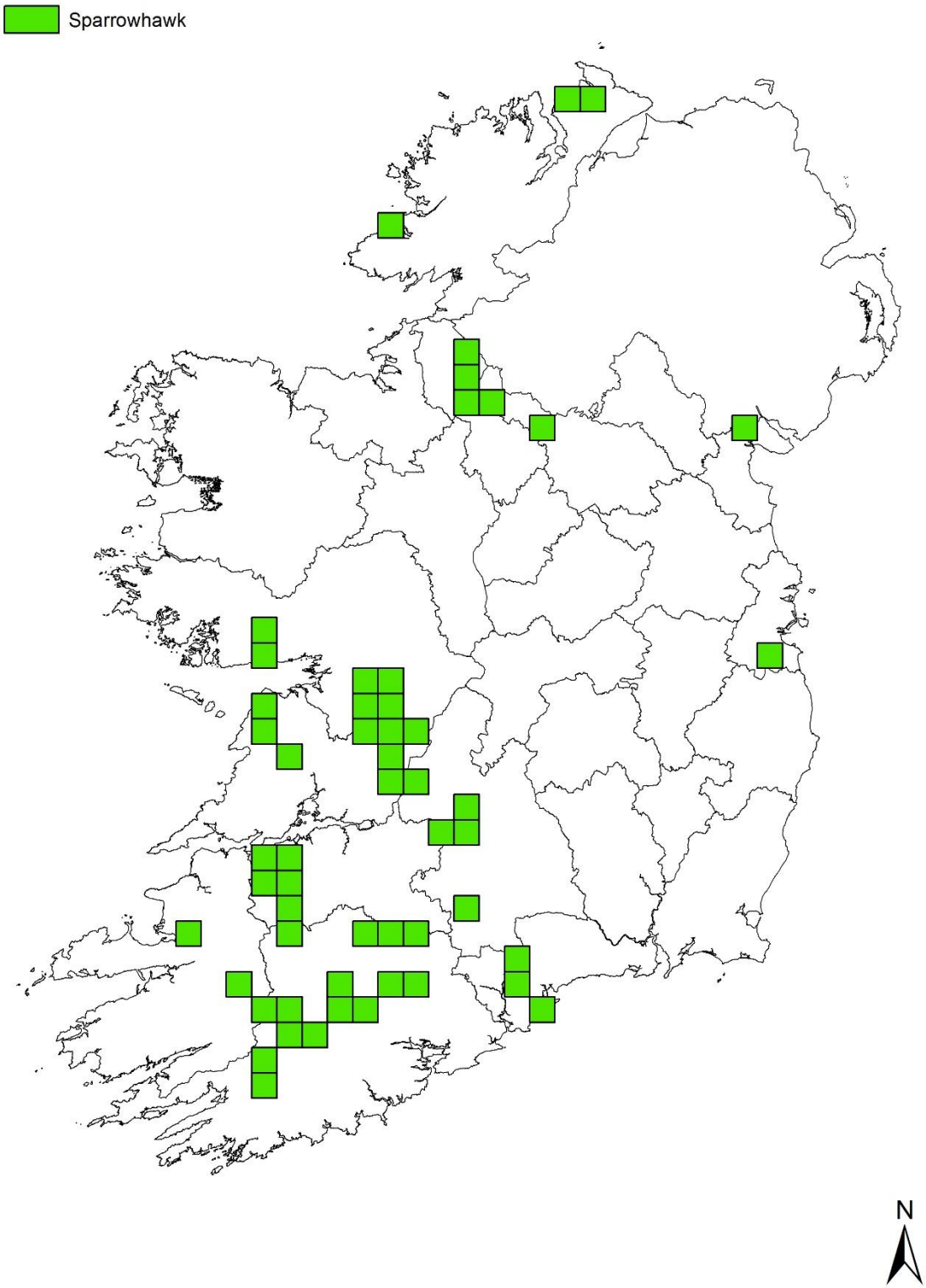
Sparrowhawk
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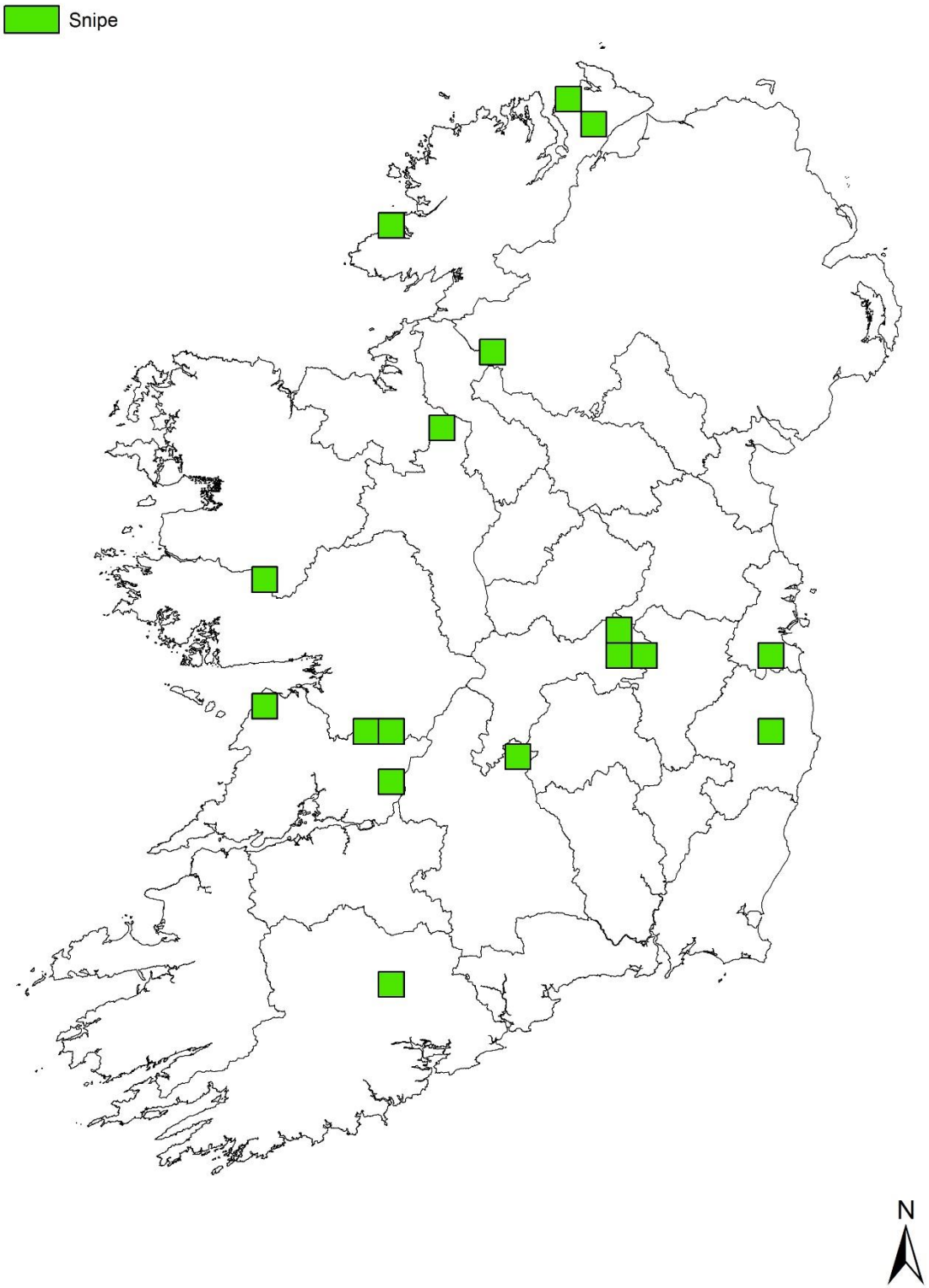
Snipe
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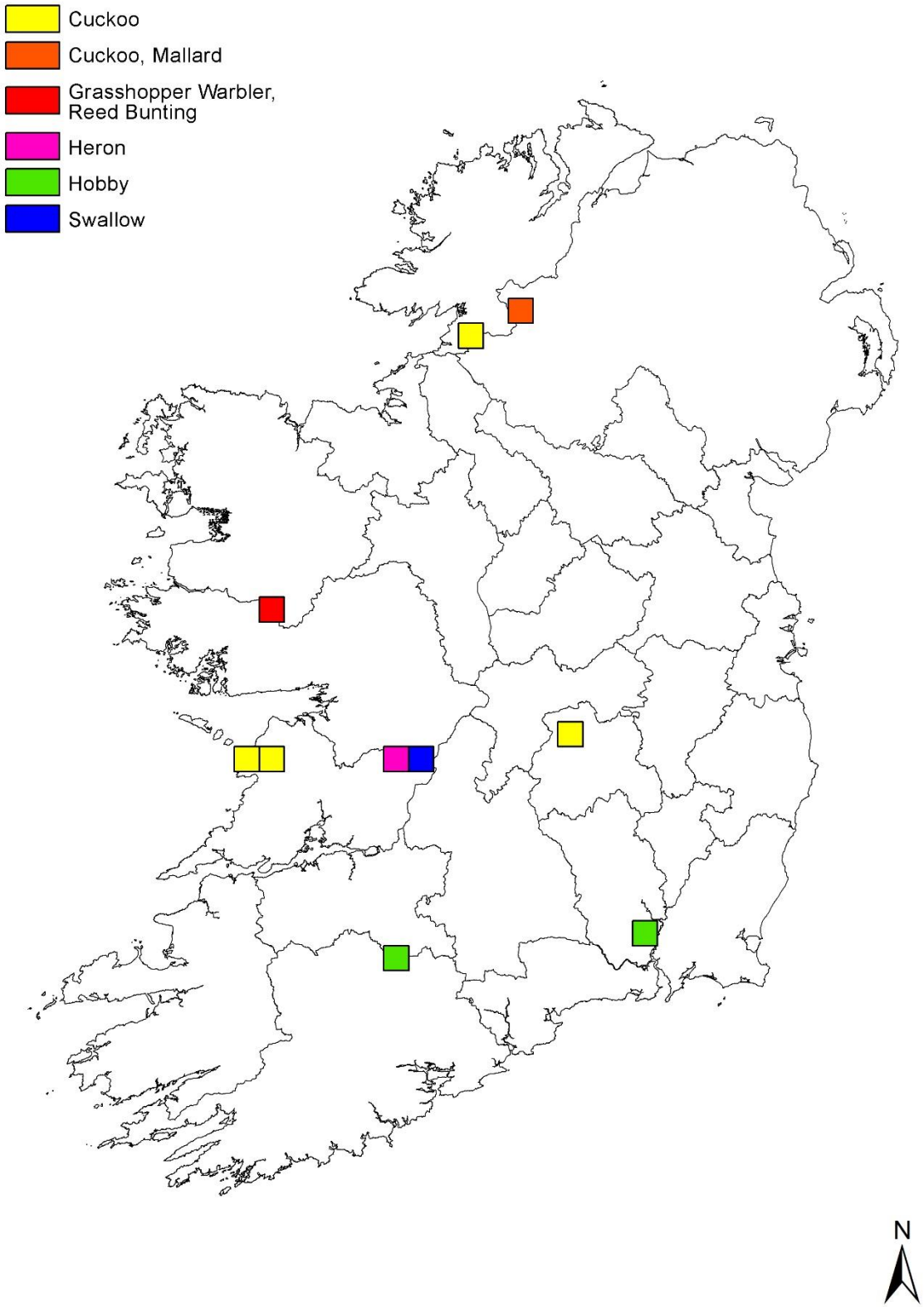
Cuckoo
Cuckoo, Mallard
Grasshopper Warbler, Reed Bunting
Heron
Hobby
Swallow
N