Republic of Ireland Hen Harrier Survey 2010

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Republic of Ireland National Hen Harrier Survey 2010

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Executive Summary

The hen harrier (*Circus cyaneus*) is a species of high conservation concern. It is listed on Annex I of the EU Birds Directive which provides a legislative framework for assessing and ensuring the conservation of the hen harrier. This framework includes monitoring, research and the designation of Special Protection Areas (SPAs). A national survey of hen harriers was carried out during 2010 with the aims of quantifying the size of the breeding population and examining changes in the national, regional and SPA populations since the previous national survey in 2005. Survey effort and results were organised according to a grid of 10km squares which were stratified according to suitability of habitat and historical hen harrier occupancy. Over 4000 hours of fieldwork were carried out in these squares by a team of volunteers and full-time fieldworkers to establish the breeding status and occurrence of hen harriers in all suitable breeding habitats.

An estimated 128 to 172 breeding pairs were recorded within 69 10km squares. The national population appears to be stable since the last national survey although the accuracy of estimates of change are complicated due to more than double the survey effort during 2010 from the 2005 survey. Regardless, there were severe regional declines noted in the Slieve Aughties and in the Stack's, Glanarudderies, Knockanefune, Mullaghareirks, North of Abbeyfeale complex. Numbers of hen harriers in other areas were observed to have increased, largely a reflection of additional field effort. The hen harrier populations within the six SPAs have declined overall by 18.1%; although these changes varied regionally; with three SPAs declining and three increasing. The number of breeding pairs in a subset of 113 10km squares surveyed in both 2005 and 2010 surveys had decreased by 6.4%. The Northern Ireland population was estimated, in a separate survey as, 59 proven and probable territorial pairs, providing an All-Ireland estimate of 158 to 205 pairs.

The majority of confirmed pairs were located in plantation forest habitats (57%), primarily in second rotation crops (43.8%) compared to open moorland (heather) habitats (23.4%); but foraging activity continues to indicate a preference for open moorland habitats. Although the data were collected over a short temporal period and are not experimental, breeding parameters suggest that current breeding resources may be limiting for hen harriers in Ireland. This should be investigated further and management targeted to maximise hen harrier productivity. More detailed data generated by other, on-going hen harrier research projects will improve the understanding of some of the trends identified by this study, and the ability to manage and conserve hen harriers.

The causes of the severe regional declines remain largely unknown, but potentially contributing factors include habitat suitability/change, persecution, development (e.g. windfarms) and various disturbance factors (e.g. peat extraction). Assessment of these factors would be greatly facilitated by the collation of existing hen harrier datasets enabling further strategic analysis of population trends and constraints across a range of spatial and temporal scales. The establishment of a long-term programme to annually monitor a sample of breeding territories for occupancy and success is also recommended. This would also provide a context within which the results of short-term studies and surveys, such as this one, could be more clearly interpreted. Further information is necessary, at regional and national levels to establish the driver(s) of regional changes. In particular to understand the effects, if any, of persecution, windfarm displacement and/or collisions and the causes of regional declines and requires further specialist studies of ranging, survival and dispersal. These strands of information are essential to understand the processes that drive harrier population dynamics in Ireland.

Collaboration

During 2010 The Irish Raptor Study Group and the Golden Eagle Trust Ltd. were awarded a competitive tender to co-ordinate the 2010 National Hen Harrier Survey on behalf of National Parks & Wildlife Service. The project was operated in collaboration with a multitude of surveyors without whose dedication and long hours the data for this project could not have been collected. Those taking part in the fieldwork included National Parks & Wildlife Service (NPWS) rangers and staff, University College Cork (UCC) hen harrier researchers, Birdwatch Ireland (BWI) staff and volunteers, Irish Raptor Study Group (IRSG) volunteers, Golden Eagle Trust volunteers and staff and numerous other independent volunteers and commercial consultants. The project was funded by the Department of Arts, Heritage and the Gaeltacht with additional funding from the Golden Eagle Trust Ltd. and R&D Avian Ecology.

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1.0 Introduction

The hen harrier (*Circus cyaneus*) is a scarce bird of prey that breeds throughout Europe and in the uplands of the UK and Ireland (Watson, 1977; Potts, 1998; Sim *et al.,* 2001; Norriss *et al.,* 2002; Sim *et al.,* 2007; Hardey *et al.,* 2009). European hen harriers traditionally nest in a variety of habitats, including cereals and grassland (Watson, 1977). Heather (*Calluna vulgaris)* dominated moorland currently appears to be the preferred breeding habitat of hen harriers in Britain (Redpath *et al.,* 1998, Sim *et al.,* 2007) whilst Irish hen harrier populations exhibit a preference towards nesting within pre-thicket forest habitats (Wilson *et al.,* 2005; Barton *et al.,* 2006; Ruddock *et al.,* 2008; Irwin *et al.,* 2008; Wilson *et al.,* 2009). In Britain young forest plantations are used to a lesser extent (Petty & Anderson, 1986; Bibby & Etheridge, 1989) and the drivers for the dissimilar habitat preferences in Ireland perhaps reflecting widespread afforestation and/or poor quality or unmanaged open/moorland habitats (Ruddock *et al.,* 2008).

The foraging habitat preferences of hen harriers are generally biased towards moorland/grassland mosaic habitats (see Amar *et al.,* 2008, Amar *et al.,* 2011) which support larger numbers of hen harrier preferred prey species, such as meadow pipit (*Anthus pratensis*) and skylark (*Alauda arvensis*). In Ireland the use of afforested habitats for foraging appears to occur more frequently than elsewhere which may be a preference or an artefact of widespread afforestation (e.g. Norriss *et al.,* 2002; O'Donoghue, 2004; Barton *et al.,* 2006; Ruddock *et al.,* 2008; Irwin *et al.,* 2008; O'Donoghue, 2010), the quality of alternative habitats and/or the differences in prey base between Ireland and Britain (and Europe) e.g. absence of short-tailed field vole (*Microtus agrestis*).

The hen harrier was once widespread in Ireland particularly in Wicklow, Kerry, Waterford, Tipperary and Galway (Thompson, 1849; Watson, 1977) but was considered scare in Mayo (Ruttledge, 1966). Hen harriers were widely persecuted in Ireland (primarily through the destruction of young and eggs) throughout the latter half of the 19th century and first half of the 20th century (Usher & Warren, 1900). The Republic of Ireland retained one of only three vestigial populations of the species within Britain and Ireland and began to recover from the 1950s (Watson, 1977). By the 1970s, the all-Ireland population was estimated at 200 – 300 pairs (Watson, 1977) but subsequently declined again through the 1980s (Watson, 1983). The all-Ireland population was estimated as approximately 180 pairs between 1988 and 1991 (Gibbons *et al.,* 1993).

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). The first survey 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 (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 downgraded from red-listed to amber-listed due to the apparent increase in the population (Lynas *et al.,* 2008). However, although the rate of decline has apparently slowed, and populations appear stable, their numbers are much lower than before the decline began (Meek *et al.,* 1998; Sim *et al.,* 2001; Norriss *et al.,* 2002; Barton *et al.,* 2006; Sim *et al.,* 2007).

In response to recommendations made by Barton et al. (2006) there has been a considerable increase in the quantity of hen harrier research in Ireland since the last national survey. This includes an on-going monitoring and research program at University College Cork (UCC) funded by NPWS and COFORD

into hen harrier ecology into habitat requirements for nesting and foraging, productivity, dispersal and survival by wing-tagging; the latter in collaboration with the IRSG (see Irwin *et al.,* 2008; Wilson *et al.,* 2009; Wilson *et al.,* 2010; O'Donoghue, 2011) and winter roost surveys (O'Donoghue, 2006 – 2011). Localised, annual monitoring is undertaken by NPWS, IRSG and other raptor workers at a sample of sites and recently the NIRSG, IRSG and Golden Eagle Trust (GET) fitted four juvenile hen harriers with satellite tags to monitor dispersal and winter ranging behaviour (Reid *et al.,* 2011; IRSG/GET, unpublished data).

The hen harrier is a species of high conservation concern in Ireland and the UK (Newton *et al.,* 1999; Gregory *et al.,* 2002, Lynas *et al.,* 2008, Eaton *et al.,* 2009) and protected regionally under The Wildlife Act 1976 & Amendment Act 2000 and in Northern Ireland under The Wildlife (Northern Ireland) Order 1985. Hen harriers are listed on Annex 1 of the Birds Directive (2009/147/EEC) and are currently considered an All-Ireland Species of Conservation Concern (Lynas *et al.,* 2008) and UK priority species (Eaton *et al.,* 2009). The EU Birds Directive provides a legislative framework of measures required for assessing and ensuring the conservation of the hen harrier which includes monitoring, research and the designation of Special Protection Areas (SPAs). Six sites have been designated as SPAs for hen harriers in Ireland (see also www.npws.ie); the Slieve Bloom Mountains SPA (Counties Laois & Offaly; Site Code 4160), the Stack's to Mullaghareirk Mountains SPA, West Limerick Hills and Mount Eagle SPA (Counties Cork, Kerry & Limerick; Site Code: 4161), the Mullaghanish to Musheramore Mountains SPA (County Cork; Site Code: 4162), the Slievefelim to Silvermines Mountains SPA (Counties Limerick & Tipperary; Site Code: 4165), Slieve Beagh SPA (County Monaghan; Site Code 4167) and the Slieve Aughty Mountains SPA (Counties Clare & Galway; Site Code 4168).

The Birds Directive also has several implications for EU member states in relation to protected species. These include the maintenance of viable hen harrier populations (Article 2); the preservation, maintenance or re-establishment of a sufficient diversity of areas and habitats (Article 3 & Article 4); the encouragement of necessary research and scientific work with regard to the objectives above (Article 10) and reporting to the Commission every three years on the progress made with respect to achieving the above requirements (Article 12). The Birds Directive thus provides a statutory and legislative basis for the national surveys by creating a requirement to monitor the hen harrier population. In addition, survey and monitoring data collected both during national and annual regional surveys are vitally important as these data are used by the government and other agencies to inform management and conservation decisions. Furthermore, given the potential for conflict of this species with shooting interests (Watson, 1977; Etheridge *et al.,* 1997; Whitfield *et al.,* 2008; Fielding *et al.,* 2009; 2010), displacement and/or mortality at upland wind farms (Bright *et al.,* 2006; 2008; Madden & Porter, 2007; Pearce-Higgins *et al.,* 2009; Fielding *et al.,* 2010) and land-use changes (Madders, 2000; Barton *et al.,* 2006). Population data derived from monitoring schemes provides a fundamental basis for determining conservation status. The UK Raptor Working Group (Anonymous, 2000) recommended that national hen harrier surveys should take place at intervals of five years, until such time as the population is not threatened by illegal killing (Sim *et al.,* 2007; see also Fielding *et al.,* 2009; 2011). Whilst the frequency of illegal persecution or specific threats are not comprehensively recorded in Ireland general and local population declines may be ongoing despite apparent short term increases noted (Barton *et al.,* 2006). Five year survey intervals were primarily enacted to monitor the effects of habitat changes in Ireland (Norriss *et al.,* 2002; Barton *et al.,* 2006).

This report utilises primary field data to address four main aims. These are to:

1) Obtain a reliable estimate of the size of the hen harrier breeding population in the Republic of Ireland;
2) Obtain a reliable estimate of the distribution of the hen harrier breeding population in the Republic of Ireland;
3) Estimate the change in population size and distribution since the last survey in 2005; and
4) Compare the distribution and size of the hen harrier populations within the six recently classified Special Protection Areas (SPAs) since the last survey in 2005.

A simultaneous UK hen harrier survey, co-ordinated by RSPB and raptor study groups, including Northern Ireland; was undertaken during 2010 therefore the All-Ireland population was monitored allowing comprehensive estimates of the breeding population derived from a single survey year.

2.0 Methods

2.1 Survey design and implementation

Potentially suitable breeding regions for hen harriers were identified according to mountain ranges/upland areas, typically within the elevation range between 200m and 600m above sea level (ASL). These areas were divided into individual survey units defined by the 10km national grid squares within these mountain ranges (see also Norriss *et al.*, 2002; Barton *et al.*, 2006). 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) and 2005 (Barton *et al.*, 2006) national surveys, or where recent occupation by hen harriers during the breeding season was known from another source. Such sources included supplemental records from 2006 to 2009 provided by the Raptor Study Group annual monitoring scheme, UCC hen harrier database, the NPWS' species database, ecological consultant data (primarily from windfarm studies) and a review, by Birdwatch Ireland, of hen harrier records from the Breeding Atlas data (2007 to 2009 inclusive). 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 233 10km squares which were considered known to or likely to contain 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) 89 'green' squares where breeding had been confirmed (see Barton *et al.*, 2006) in the period 1998 – 2009; ii) 31 'yellow' squares where breeding had been recorded as possible (see Barton *et al.*, 2006) breeding records iii) 47 'orange' squares in which hen harriers had been sighted and/or where suitable habitat was recorded and iv) 65 squares which had no historical hen harrier sightings and/or limited suitability of habitat (n = 65).

Geo-referenced OSI 1:50000 maps and aerial photographs for each of the 10km survey squares survey were digitised using ArcView 9.3 and provided to fieldworkers. The maps included the OSI 1:50000 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 A). The aerial photographs (taken in 2005) showed in further detail the extent of forest boundaries and allowed discrimination between improved grassland and unimproved grassland/moorland and afforested habitats (see Appendix B). The names and contact details of potential fieldworkers were derived from the contact databases of regional hen harrier researchers, the NPWS staff contacts database, the Irish Hen Harrier Winter Survey database, the University College Cork (UCC) hen harrier research team, IRSG members and Birdwatch Ireland staff and members, ecological consultants and other independent raptor fieldworkers. Fieldworkers were invited to participate in the survey and to attend training workshops via email and telephone contact. Five workshops were undertaken to standardise fieldwork methods, distribute maps, distribute aerial photographs and allocate survey squares.

2.2 Field survey methods and recording

In order to establish population estimates the primary objective of the hen harrier field survey was to establish whether suitable habitat was occupied by breeding hen harriers. Secondary objectives were to establish whether a breeding attempt was initiated and to establish breeding outcome.

Prior to commencing the survey fieldworkers used aerial photographs and maps to exclude unsuitable habitat, identify areas of potentially suitable hen harrier breeding habitat and locate suitable vantage points for timed observations. The suitability of these areas was confirmed during the first visit by driving through the square to "ground-truth" likely breeding habitats. Suitable breeding habitat was 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 rotation crops). Ground above 600m; built-up/urban areas or within 100m of occupied farms and dwellings; improved pasture and arable farmland; the interior of unbroken, closed-canopy forest blocks; sheep-walk; extensive areas of bracken; degraded or overgrazed upland areas without any heather cover and areas within close proximity to sea-cliffs, inland crags, rocky outcrops, boulder fields and scree slopes were classified as unsuitable habitat and were excluded on maps and from survey effort (see Hardey *et al.,* 2009).

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 regularly in Northern Ireland (Watson, 1991; Scott *et al.,* 1991; 1992; 1993; Mellon *et al.,* 2005; Ruddock *et al.,* 2008) and harriers will often nest in rides or open lacunas 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.

Survey squares were due to be visited on at least four occasions between late March and the end of July. Firstly, two visits to establish territorial occupancy were recommended with the first visit between late March and mid-April and the second between mid-April and mid May. A third survey visit was recommended during late May and late June to establish evidence of breeding, with particular emphasis on locating active nests, where these were not already located. A fourth obligatory visit was required between late June and the end of July to confirm nest activity and where fledged were observed breeding outcome. These survey visits reflect the seasonality of the hen harrier breeding activities (see Table 1) and included the periods of territorial display/mate advertisement, incubation, nestling and fledgling periods (Hardey *et al.,* 2009). Methods were similar to those utilised in the previous national survey (Barton *et al.,* 2006), but with an extra visit during late May to late June to increase the likelihood of detecting a nest location (Hardey *et al.,* 2009).

Table 1. Summary of hen harrier breeding season (Hardey et al., 2009).

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	-

Hen harriers can breed in close proximity to each other (Watson, 1977; Balfour & Cadbury, 1979; Simmons, 2000; Garcia & Arroyo, 2002; 2004) 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 due to be resurveyed during each subsequent visit.

For the purposes of this report a territory is defined as any area of suitable habitat 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 1:50000 map closest to the area of suitable habitat surveyed. The date, place-name (derived directly from the 1:50000 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 sighting (six figure grid reference), number, age and sex of all hen harriers encountered. Also recorded were a brief description of behaviour (particularly where indicative of breeding activity, see Table 2) and the dominant habitat type(s) within 100m of the sighting (see Table 3). 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, 2010) were provided to fieldworkers to distinguish the more subtle differences in plumage and behaviour between harriers of different sex and age combinations. Adult males are pale grey with black wing-tips, adult females are larger than males and predominantly brown, juveniles are also brown but darker and more neat-plumaged than adult females and second calendar year males usually appear grey and brown with a notable dark-saddle where brown mantle and scapular feathers are typically retained. All sexes and ages of hen harriers exhibit a distinctive white rump patch.

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

Behaviour (Code)	Description of behaviour
Displaying (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)	Non-hunting flight or commuting where no other behaviours are recorded
Alarming (A)	Adults calling or appearing agitated, usually occurs close to the nest during territorial defence
With Prey (WP)	Carrying prey in it's talons
Soaring (S)	Circling very high (above tree-tops)
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)	Describe behaviour(s) where not indicated by any other category above

Fieldworkers visually followed 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. The survey organisers liaised with fieldworkers throughout the season via email and phone updates to improve survey coverage where required and provide 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).

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.

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.
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 *Calluna* and bell heather, bog cotton, deer grass and moss. Typically grazed by deer and low densities of sheep.
Grass moorland (G)	Unenclosed grass-dominated moorland usually grazed by sheep. Characterised by species such as wavy hair grass, mat grass and heath rush. Stands of *Juncus* spp. and bracken occasionally occur.
Rough grazing (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 grazing (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 outwith plantation forests consisting of willow, bramble, furze etc. Includes bushy vegetation such as Willow (*Salix* spp), Gorse (*Ulex* spp), Bramble (*Rubus* spp), Alder (*Alnus* spp), Birch (*Betula* spp) and Bracken (*Pteridium* spp).
Other (O)	Description of habitat where it does not fall into one of the categories outlined above.

2.3 Other research

During fieldwork, surveyors specifically recorded the presence of wing-tagged hen harriers, sightings of other raptor species (including six figure grid references) and noted other upland species (e.g. red grouse, golden plover) for submission to the Breeding Bird Atlas project. In addition, fieldworkers who held nest visitation licences searched nest areas for moulted feathers and prey remains during nest visits and other fieldworkers visited nests after the breeding season to search for these samples. Protocols for the collection, storage and labelling of samples were provided to fieldworkers (see Appendix C & D).

2.4 Calculation of 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'. 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 within an appropriate distance). Where a territory was classified as confirmed or possible despite only a single bird having been recorded during observations it was termed 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 possible breeding pair (e.g. male bird seen displaying on multiple occasions; see Table 4).

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 (see Section 2.1) 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. Where estimates were available from the 1998 – 2000 (Norriss *et al.,* 2002) and 2005 (Barton *et al.,* 2006) hen harrier surveys the national and regional population changes were examined by calculating the percentage change in the estimates across the three surveys. In addition, a second estimate of regional population change was derived by comparing the total number of pairs found in the subset of squares surveyed during both the 2005 and 2010 national surveys. High density areas were defined as 10km squares where a minimum of three confirmed or possible territories were recorded (Barton *et al.,* 2006).

The survey in Northern Ireland was carried out simultaneously and preliminary results were obtained from the Northern Ireland Raptor Study Group and RSPB (D. Hayhow, personal communication). As per Barton *et al.,* (2006) survey definitions in the UK of 'proven' and 'probable' (see Sim *et al.,* 2001; 2007) correspond closely to definitions of confirmed and possible utilised here. Single males in the UK are considered as evidence of 'possible' breeding and were excluded from the combined figures presented here, but pairs and/or females from the UK 'possible' criterion were added to the estimates for All-Ireland. Previously Barton et al. (2006) combined the confidence intervals from the Northern Ireland survey to obtain an All-Ireland estimate, but since no confidence intervals were available we have combined categories to obtain minimum estimates (confirmed + proven (NI)) and maximum estimates (confirmed + possible + probable (NI) + females/pairs (NI)).

2.5 Assessment of population estimates and population changes within SPAs

Estimates of population change were calculated, where possible, for the six SPAs designated for hen harriers in Ireland. The areas which were surveyed during both the 2005 (pre-designation) and 2010 (post-designation) surveys were identified and the numbers of breeding pairs found were contrasted between the two surveys. This was achieved, firstly, by comparing the 10km square summaries for each of these areas between the two 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).

2.6 Calculation of breeding outcomes and nest habitat

The breeding activity at nest locations was established through licenced nest visits (i.e. clutch counts, brood counts, wing-tagging etc), nest cameras and behavioural observations (Hardey *et al.*, 2006; 2009). The latter were commonly used to infer whether incubation had started. Before incubation begins, females typically do not fly from the nest to receive a food-pass, and do not return to the nest 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 wildlife licences and visited nest locations to monitor breeding performance recorded clutch size, brood size and the number of fledged young. Nest visits prior to incubation were avoided due to the potential sensitivity of breeding harriers to disturbance at this time (Hardey *et al.* 2006; 2009).

Territories were classified as 'successful' where at least one young fledged (Green & Etheridge, 1999; Barton *et al.*, 2006). Breeding failure was determined either i) by nest visits, ii) when no activity was recorded on third and fourth visits to the area of a previously active nest, iii) if no 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; clearfell; 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.

2.7 Calculation of plantation forest habitat changes between surveys

Information on the plantation forest habitats within Ireland and within the hen harrier SPAs was derived from two sources; the Forest Service data (Forestry 07; FIPS 98 & 2006 – 2009 sub-compartment databases) and the Coillte sub-compartment database. These databases were utilised to derive information on forest structure and age classes during 2005 and 2010, and to contextualise any observed changes in the hen harrier population. Where available, the information included tree species planted, year of planting and sub-compartment size (hectares). Sub-compartment database polygon themes were edited using ArcGIS 9.3 to calculate areas of each sub-compartment and forest polygons were "clipped" using the SPA polygons to create a sub-set of forest data within each SPA. Areas of each sub-compartment and the year of planting were used to establish the extent of suitable breeding habitat for hen harriers within each forest age class (1 year, 2 – 5 years, 6 – 9 years, 10 – 15 years) or unsuitable (>15 years) across Ireland and within each hen harrier SPA. Where sub-compartment data were replicated in more than one GIS databases analyses excluded overlapped areas and were completed and presented separately.

3.0 Results

3.1. Survey implementation, coverage and data submission

A review of existing and historical breeding records between 1998 and 2009 identified 233 10km squares for survey coverage. There were 89, 31, 47 and 65 squares allocated to each of the four priority groups (Figure 1; see Methods 2.1) respectively. Geo-referenced field maps and aerial photographs were created for all these squares (see Appendix A & B). A database comprising 418 email addresses and names was compiled and over 2000 emails were distributed prior to the survey start to invite participation in the workshops and survey effort. There were 91 people that initially signed up to the workshops and ultimately there were 109 people that attended the five workshops. These were delivered in four strategic areas to facilitate accessibility for all fieldworkers; namely Charleville, (Co. Cork; n = 2), Athlone (Co. Westmeath), Donegal town, (Co. Donegal) and Wicklow Mountains National Park, (Co. Wicklow).

Monthly updates were provided via email and on the Golden Eagle Trust website to all participants and the fieldworker database. Communication via phone and email was maintained by the project manager with fieldworkers on demand throughout the season. Data were received from fieldworkers by post and digitally between the 28th August and 18th November 2010. Data were digitised, aggregated and analysed between the 13th September and the 2nd February 2011. Further clarification on grid references, habitat, and site names was on-going with fieldworkers until the 9th March 2011.

Prior to the start of the breeding season, in late March/early April, there were 162 (69.5%) priority 10km squares allocated to surveyors which included 97.8% (n = 87) 'green' squares; 64.5% (n = 20) 'yellow' squares; 57.4% (n = 27) 'orange' squares and 42.4% (n = 28) 'red' squares respectively (see Methods 2.1). Data was received for a total of 149 10km squares surveyed during 2010 (Figure 2).

There were 128 (79%) of the squares which were initially selected by fieldworkers covered whilst an additional 10 squares not initially allocated were also covered. Data was also received for a further 11 squares not identified in the data review. Overall, 85.4%, 51.6%, 51.1% and 33.8% of each priority category squares (see Methods) were surveyed. This equates to 87.4%, 80%, 88.9% and 71.4% of the initial allocated coverage. There was data received for an additional 11 squares not identified in the data review. A further 34 squares which were initially allocated for survey either did not receive any coverage or no data was received.

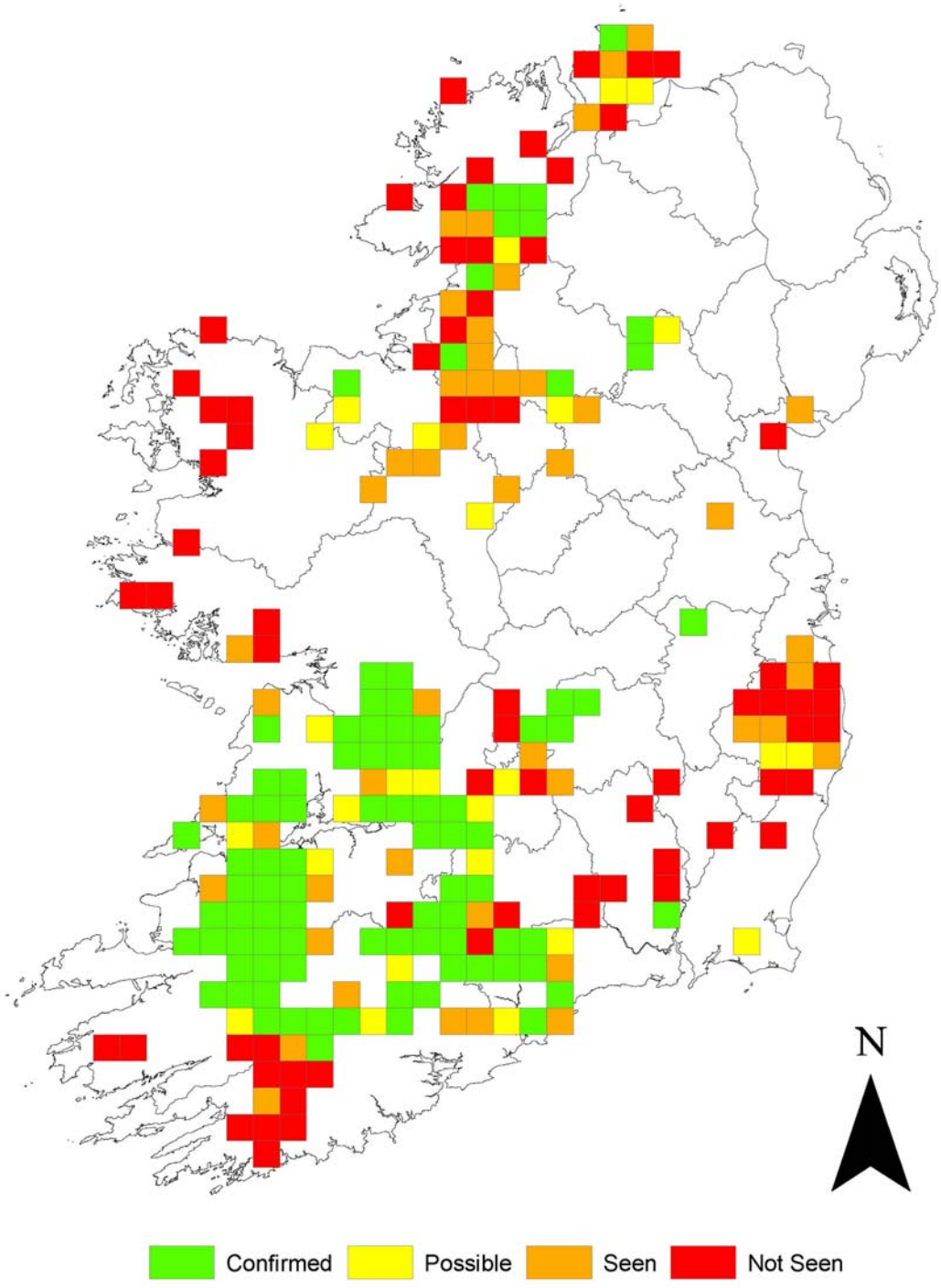

Figure 1. Map showing distribution of 10km squares identified in review prioritised for coverage based on i) green = confirmed breeding records between 1998 – 2009; ii) yellow = possible breeding records between 1998 – 2009; orange = hen harriers seen between 1998 – 2009 and iv) red = suitable habitat, random survey squares and/or within historical range of the species but no breeding records between 1998 – 2009.

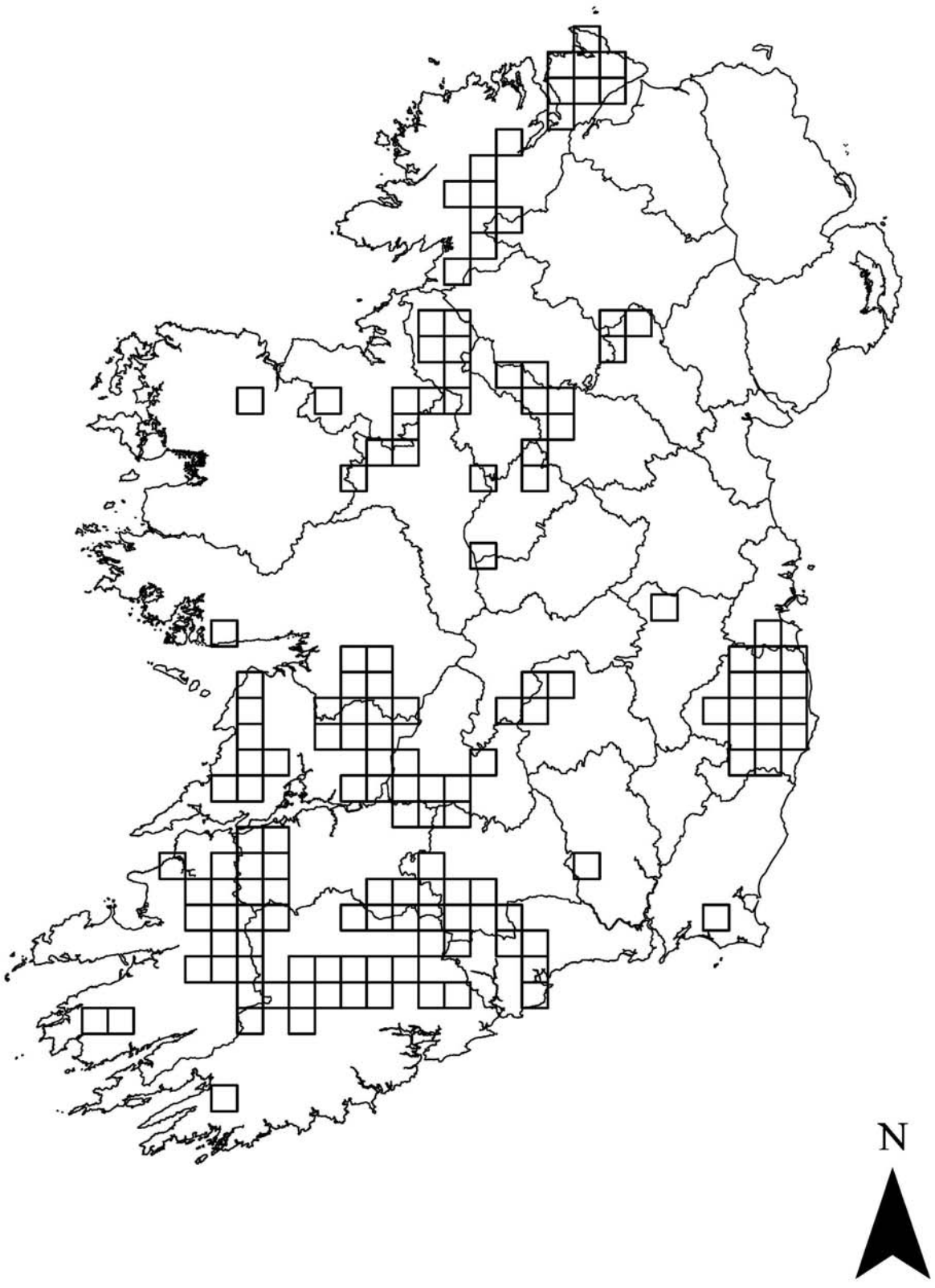

Figure 2. Map showing distribution of 10km squares which were surveyed during 2010.

3.2 Survey effort and observations

A total of 2712 records were submitted for analysis. These were derived from 2030 vantage point records, 42 casual sightings and 117 hen harrier research records (i.e. nest visits, nest cameras, wing-tagging of young and trapping of adults). These latter records were primarily derived from the on-going program of research by UCC and NPWS. The records received covered the period 12th February 2010 to 4th September 2010. Five records were consequently classified as non-breeding records and the breeding season records analysed were from between 15th March 2010 and 31st August 2010.

The minimum total field effort for all breeding season monitoring was 4085 hours 36 minutes. There were 2008 vantage point records and 35 casual observations incorporated into the breeding season analysis. Effort data was recorded for 1651 (82.2%) vantage points and casual observations and comprised 4074 hours and 26 minutes whilst the remainder (11 hours 10 minutes) was classified as research specific effort.

Vantage point and casual observations were undertaken between 0545h and 2225h and ranged in duration from one minute to 8 hours 30 minutes, with an average duration of 2 hours 28 minutes (n = 1651). There were 1025 (51%) vantage points which did not detect any hen harriers whilst the other 983 vantage points recorded between one and 17 separate observations.

A total of 1540 hen harrier sightings were recorded from vantage points and casual observations which represents an overall detection rate of 0.4 hen harriers per hour of observation. Hen harrier sightings were recorded between 0620h and 1953h (n = 730) and the duration of hen harrier sightings ranged between one minute and 1 hour 30 minutes (n = 359; ~5 minutes 43 seconds). The frequency of occurrence of all sexes/ages appeared to decline in the latter part of the day (Figure 3).

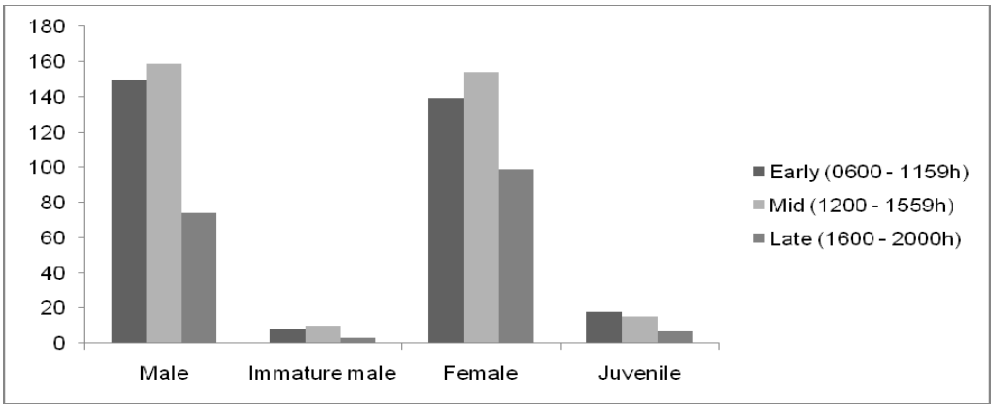

Figure 3. Graph showing the aggregated distribution of hen harrier observations (n = 730) throughout the diurnal period during three arbitrarily defined time periods: early (0600– 159), mid (1200–1559h) and late (1600–2000h).

Observations were comprised primarily of independent adult males (35.6%), independent adult females (28.3%) and male(s) seen simultaneously with female(s) (23.1%; see Table 5 & 6). 61% of all sightings were of at least one adult male (n = 943 total observations of 973 males, Table 5) with up to three males seen simultaneously whilst immature males were recorded relatively infrequently (3.2% of all sightings; n = 50). Between one and three females were observed simultaneously and up to five juveniles were seen simultaneously. The most frequently observed hen harrier behaviours were hunting (18.2%), flying (23.8%) or circling (10.5%; Tables 7 & 8).

Table 5. Summary of sightings of hen harriers categorised by age and/or sex

Sex/age	Total Observations	Number of birds
Adult male	943	973
Adult female	865	890
Immature male	50	50
Juveniles	110	213
Unknown	39	-

Table 6. Summary of sightings of hen harriers categorised by age and/or sex where applicable

Sex/age	Total Observations	Total number of birds
Adult male only	548	569
Female only	437	445
Immature male only	27	27
Juveniles only	46	83
Male(s) & female(s)	356	364 & 373
Male & immature & female	13	14 & 13 & 13
Immature male & female	8	8 & 8
Immature male & adult male	2	2 & 2
Female & juvenile	40	40 & 82
Male & juvenile	13	13 & 23
Pair & juvenile	11	11 & 11 & 23
Unknown sex/age	39	-

Table 7. Behavioural observations of individual hen harrier sightings recorded by fieldworkers showing the overall number of observations & % occurrence, categorised by the sex of individual hen harrier observations.

Behaviour	Observations (n)	Total % occurrence	Male only	Female only	Immature only	Juveniles only
Displaying	155	7.2	56 (36.1)	9 (5.8)	6 (3.9)	0 (0.0)
Food pass	183	8.5	13 (7.1)	7 (3.8)	0 (0.0)	2 (1.1)
Hunting	392	18.2	215 (54.8)	117 (29.8)	5 (1.3)	2 (0.5)
Flying	512	23.8	196 (38.3)	173 (33.8)	8 (1.6)	24 (4.7)
Alarming	80	3.7	16 (20.0)	44 (55.0)	0 (0.0)	0 (0.0)
With prey	98	4.6	42 (42.9)	26 (26.5)	0 (0.0)	0 (0.0)
Soaring	159	7.4	48 (30.2)	60 (37.7)	8 (5.0)	1 (0.6)
Circling	225	10.5	60 (26.7)	99 (44.0)	9 (4.0)	5 (2.2)
Perched	83	3.9	24 (28.9)	14 (16.9)	0 (0.0)	6 (7.2)
On ground	78	3.6	15 (19.2)	28 (35.9)	1 (1.3)	4 (5.1)
Mobbing	44	2.0	18 (40.9)	9 (20.5)	0 (0.0)	0 (0.0)
Other	153	7.1	36 (23.5)	23 (15.0)	0 (0.0)	6 (3.9)

Table 7 continued. Behavioural observations of multiple hen harrier sightings recorded by fieldworkers showing the overall number of observations and % occurrence and categorised by the sex of hen harrier observations.

Behaviour	Male & female	Male, immature & female	Immature male & female	Immature male & adult male	Female & juvenile	Male & juvenile	Pair & juvenile	Unknown sex/age
Displaying	72 (46.5)	8 (5.2)	1 (0.6)	2 (1.3)	0 (0.0)	0 (0.0)	1 (0.6)	0 (0.0)
Food pass	130 (71.0)	0 (0.0)	1 (0.5)	0 (0.0)	19 (10.4)	5 (2.7)	6 (3.3)	0 (0.0)
Hunting	33 (8.4)	3 (0.8)	0 (0.0)	0 (0.0)	4 (1.0)	1 (0.3)	1 (0.3)	11 (2.8)
Flying	78 (15.2)	4 (0.8)	0 (0.0)	0 (0.0)	13 (2.5)	4 (0.8)	3 (0.6)	9 (1.8)
Alarming	14 (17.5)	0 (0.0)	0 (0.0)	0 (0.0)	5 (6.3)	1 (1.3)	0 (0.0)	0 (0.0)
With prey	18 (18.4)	1 (1.0)	0 (0.0)	0 (0.0)	6 (6.1)	3 (3.1)	2 (2.0)	0 (0.0)
Soaring	37 (23.3)	2 (1.3)	0 (0.0)	0 (0.0)	1 (0.6)	0 (0.0)	0 (0.0)	2 (1.3)
Circling	43 (19.1)	1 (0.4)	3 (1.3)	0 (0.0)	2 (0.9)	0 (0.0)	3 (1.3)	0 (0.0)
Perched	27 (32.5)	2 (2.4)	0 (0.0)	0 (0.0)	7 (8.4)	1 (1.2)	2 (2.4)	0 (0.0)
On ground	23 (29.5)	1 (1.3)	1 (1.3)	1 (1.3)	4 (5.1)	0 (0.0)	0 (0.0)	0 (0.0)
Mobbing	14 (31.8)	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.3)	0 (0.0)	2 (4.5)	0 (0.0)
Other	64 (41.8)	1 (0.7)	2 (1.3)	0 (0.0)	8 (5.2)	1 (0.7)	1 (0.7)	11 (7.2)

The sightings were classified to at least one habitat type for 70.2% of observations (n = 1080; n = 1624 habitat records). The most frequent habitat category recorded was heather moorland (Table 8) although afforested habitats were recorded more frequently (49.4%) than open habitats (44.8%). Hunting was recorded most frequently in heather moorland (34%; see Table 9) and foraging was observed less frequently in afforested (42.5%) than in open habitats (53.4%).

Table 8. The habitats within which all observations were recorded

Habitat type	Occurrence (n)	Occurrence (%)
*First rotation forest (1F)**	213	13.1
*Second rotation forest (2F)**	346	21.3
*Thicket (T)**	185	11.4
*Clearfell (CF)**	58	3.6
Heather moor (H)$	473	29.1
Grass moor (G)$	54	3.3
Rough grazing (RG)$	92	5.7
Improved grazing (IG)$	38	2.3
Scrub (S)$	71	4.4
Other (O)	94	5.8

* 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 9. The habitats within which hunting, i.e. foraging, observations were recorded

Habitat type	Occurrence (n)	Occurrence (%)
*First rotation forest (1F)**	60	12.1
*Second rotation forest (2F)**	83	16.8
*Thicket (T)**	44	8.9
*Clearfell (CF)**	23	4.7
Heather moor (H)$	168	34.0
Grass moor (G)$	21	4.3
Rough grazing (RG)$	40	8.1
Improved grazing (IG)$	16	3.2
Scrub (S)$	19	3.8
Other (O)	20	4.0

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

Vantage point observations within the database of effort and sightings were verified and standardised by place name and grid reference for each putative territory. Each territory was analysed by collating sightings, sex/age and behaviour to establish breeding activity at each territory and assigning these into one of the four visit times (see Methods 2.2). There were 21 records received which did not indicate the month and/or day of the observation and therefore could not be assigned a visit time. There were 511 putative territories identified from the vantage point records i.e. an area of suitable habitat and/or an area in which hen harriers were observed. A total of 2217 visits (including vantage

points, casual observations and hen harrier research work) were used to establish breeding status and outcome. Between one and 86 observations were carried out at suitable habitat (average 4.3 ± 0.2 SE visits) and between one and 22 visits/camera observations were recorded (average 0.2 ± 0.1SE visits). First visits were carried out at 58.7% (n = 300) of territories, second visits at 80.6% of territories (n = 412) third visits at 49.9% of territories (n = 255) and fourth visits at 53.6% of territories (n = 274).

3.3 Other research

There were 285 records received for other bird species (see Table 10), this included seven other species of diurnal raptor, and two species of owl. Short-eared (*Asio flammeus*) was also recorded by one observer (D. Watson, personal communication), but no digital record was received to confirm the location. The distribution of raptor records was widespread, although few records were received of confirmed breeding for each species (see Appendices E – M) probably as a result of prioritisation of survey effort towards the collection of hen harrier records and observations not being targeted at confirming breeding distribution or status of these other species *per se*.

Table 10. The records of other bird species collected during hen harrier surveys.

BTO Code	Common name	Latin name	Number of records	Number of 10km squares
ML	Merlin	*Falco columbarius*	10	10
BZ	Buzzard	*Buteo buteo*	29	18
K	Kestrel	*Falco tinnunculus*	114	43
PE	Peregrine	*Falco peregrinus*	16	10
SH	Sparrowhawk	*Accipiter nisus*	27	17
GI	Goshawk	*Accipiter gentilis*	3	3
KT	Red kite	*Milvus milvus*	1	1
LE	Long-eared owl	*Asio otus*	1	1
BO	Barn owl	*Tyto alba*	1	1
FV	Red-footed falcon	*Falco vespertinus*	2	1
RN	Raven	*Corvus corax*	21	17
RG	Red grouse	*Lagopus lagopus*	8	7
GP	Golden plover	*Pluvialis apricaria*	8	6
CK	Cuckoo	*Cuculus canorus*	12	7
S.	Skylark	*Alauda arvensis*	1	1
MP	Meadow pipit	*Anthus pratensis*	1	1
CU	Curlew	*Numenius arquata*	3	3
SN	Snipe	*Gallinago gallinago*	1	1
L.	Lapwing	*Vanellus vanellus*	2	2
HC	Hooded crow	*Corvus corone cornix*	18	10
SL	Swallow	*Hirundo rustica*	2	2
WK	Woodcock	*Scolopax rusticola*	1	1
J.	Jay	*Garrulus glandarius*	1	1
BR	Brambling	*Fringilla montifringilla*	1	1
Y.	Yellowhammer	*Emberiza citrinella*	1	1

Details of nest visits, under licence, and/or post-fledging searches for prey remains and/or moulted feathers were submitted for analysis from five locations. There were 29 prey remains submitted for identification and comprised primarily of passerines, namely meadow pipits and skylarks. Genetic samples of hen harrier feathers were submitted only from a single nest at which at least one chick was apparently predated, since "chewed ends" to the feathers were evident (see Appendix N).

3.4 Calculation of population estimates, population change and breeding density

The survey identified 128 confirmed and 44 possible hen harrier breeding pairs (Table 11; Hardey *et al.,* 2009), with a further eight confirmed breeding pairs from border counties of Northern Ireland (Fermanagh & Tyrone). Since the determination of breeding status was based on behavioural observations (Table 4), occupancy was further classified according to the number and age of breeding birds at each territory, with adult pairs recorded at most (94.5%) of the confirmed territories (Table 12). There was a single case of possible polygyny where an adult male was observed food passing to two separate females in April, but no further evidence of breeding was obtained at either location subsequently.

Hen harriers were observed at 111 putative territories where insufficient evidence was obtained to classify a distinct breeding attempt. There were 218 putative territories classified as not occupied i.e. where no hen harriers were observed in suitable breeding habitat and/or within historically occupied territories. Therefore, hen harriers were observed at least once in 55.4% of the areas of suitable breeding habitat included in this survey. Five records of hen harriers at territories were submitted from outside the breeding period (i.e. wintering records); three of these locations were identified as breeding territories.

Table 11. Breeding population of hen harriers in Ireland in 2010, 2005 and 1998 – 2000, showing overall population change.

Breeding status	1998-2000	2005	2010	% change 2005 - 2010
Confirmed	102	132	128	-3.1%
Possible	27	21	44	52.3%
Range	**102 - 129**	**132 - 153**	**128 - 172**	-

Table 12. Occupancy by hen harriers within the survey breeding status categories

Occupancy	Confirmed	Possible	Seen
Adult pair	121	30	24
Immature male + adult female	2	0	1
Single adult male	4	3	51
Single female	1	6	17
Single immature male	0	5	17
Single ringtail	-	-	1

During 2010, confirmed pairs were located in 62 squares and possible pairs in 33 squares, of which only seven were distinct from the confirmed breeding range (Figures 4 & 5). Additionally, hen harriers were seen in 62 squares, of which only 25 squares were unique and did not contain confirmed or possible breeding territories (see Figure 4). The number of confirmed records in individual 10km squares ranged between one and seven confirmed territorial pairs and between one and three possible pairs with a maximum of nine confirmed plus possible pairs (Figure 6). During 2005, breeding was confirmed in 60 squares and possible within 19 squares with six uniquely occupied squares (Figure 7), with gains and/or losses in several squares (Figure 7 & 8). Therefore, the total breeding range was 69 squares during 2010 and 66 squares in 2005.

To reduce confounding effect of increased observer effort on results comparative measures of population changes since the previous national survey were analysed using the subset of 113 squares surveyed during both the 2005 and 2010 surveys. This shows a 6.4% decline in confirmed pairs (117 pairs in 53 10km squares in 2010 and 125 pairs in 53 10km squares in 2005; Figures 7-9). The number of possible breeding pairs increased by 53.7% between the surveys and an increase in distribution (41 pairs in 29 10km squares in 2010 compared to 19 pairs in 18 10km squares in 2005; Figures 7, 8, 10-12).

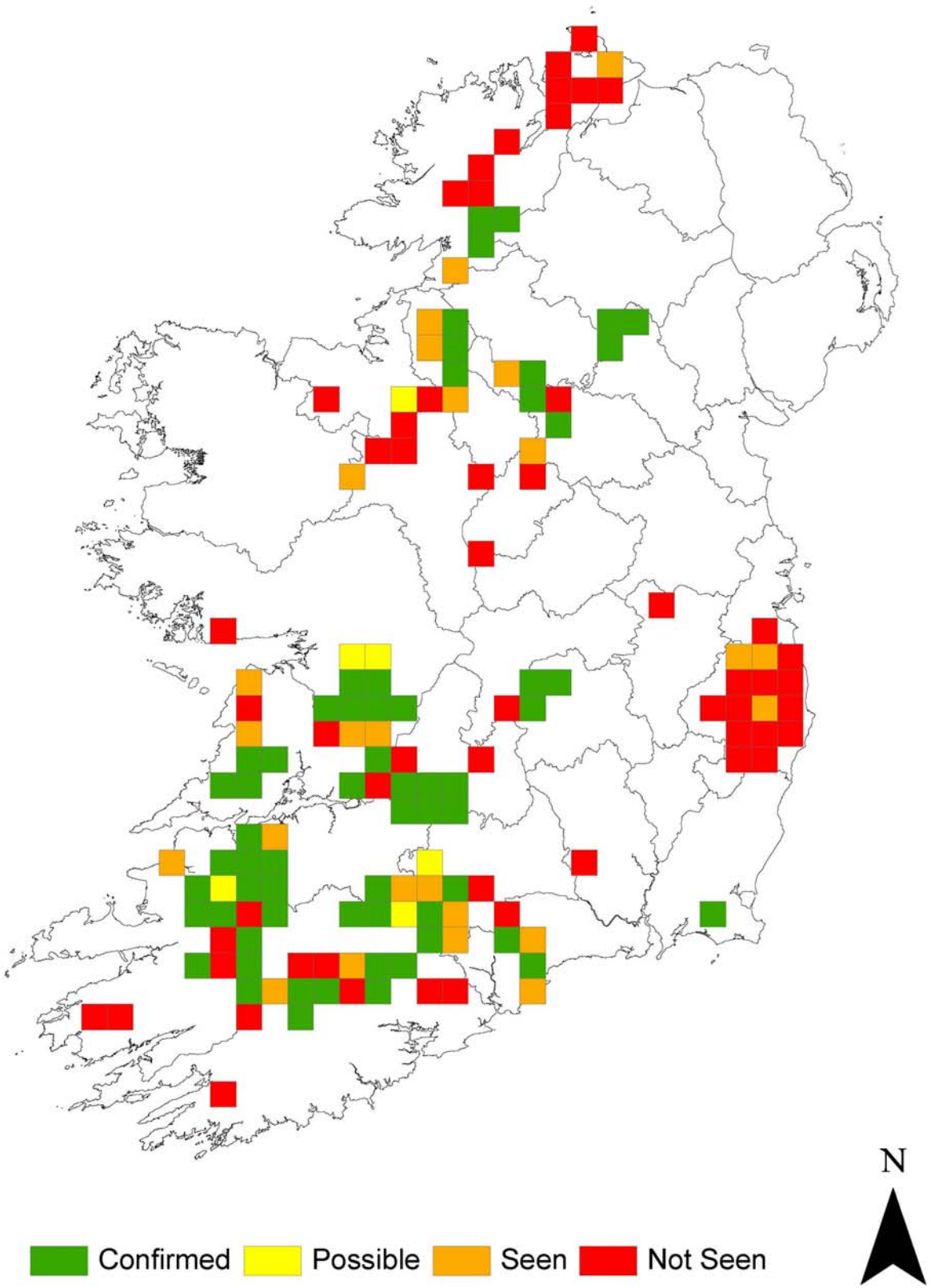

Figure 4. Distribution of breeding hen harriers within 10km squares surveyed during 2010, classified by breeding status

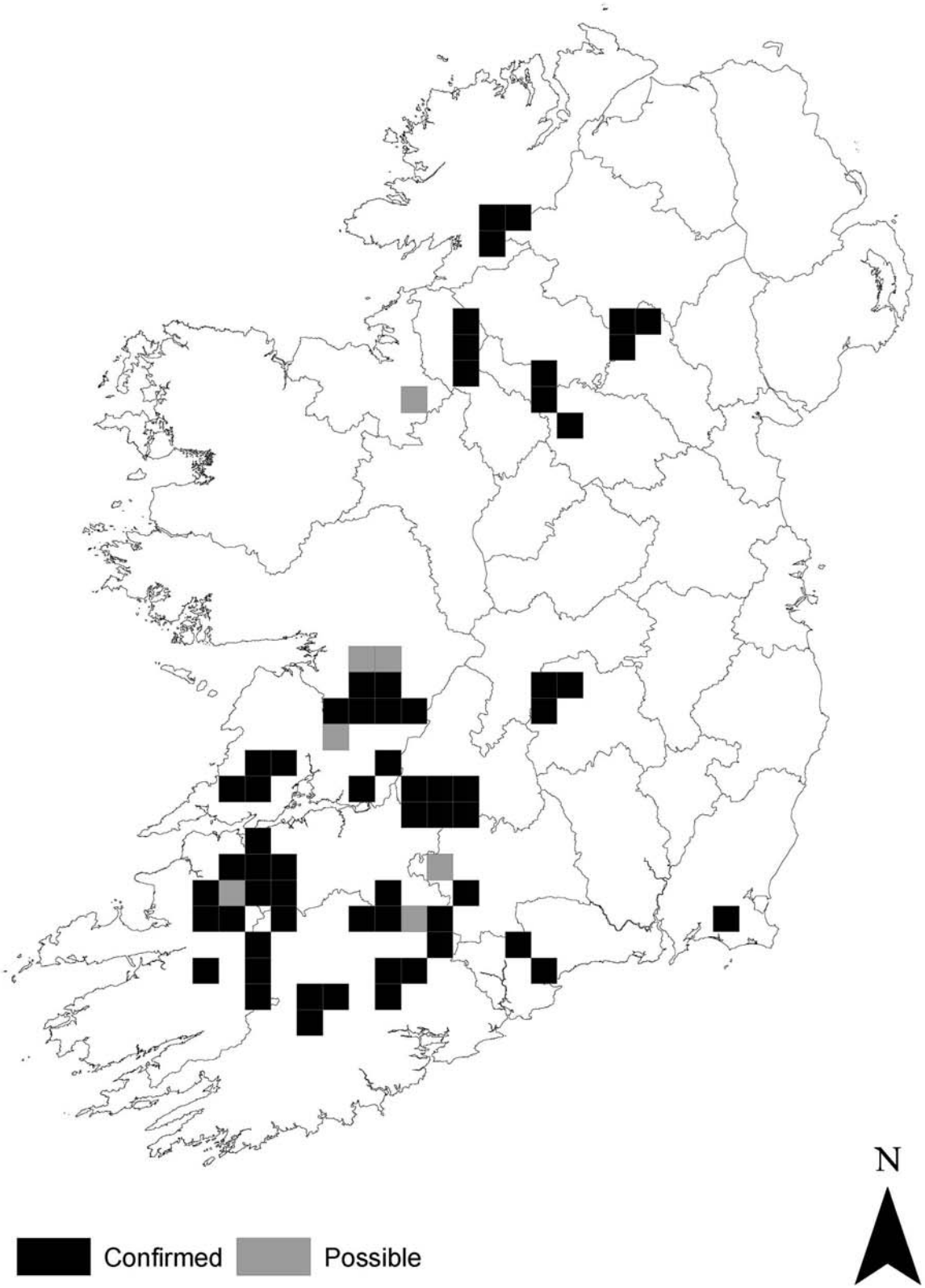

Figure 5. Distribution of 10km squares which contained confirmed and/or possible breeding hen harriers in 2010.

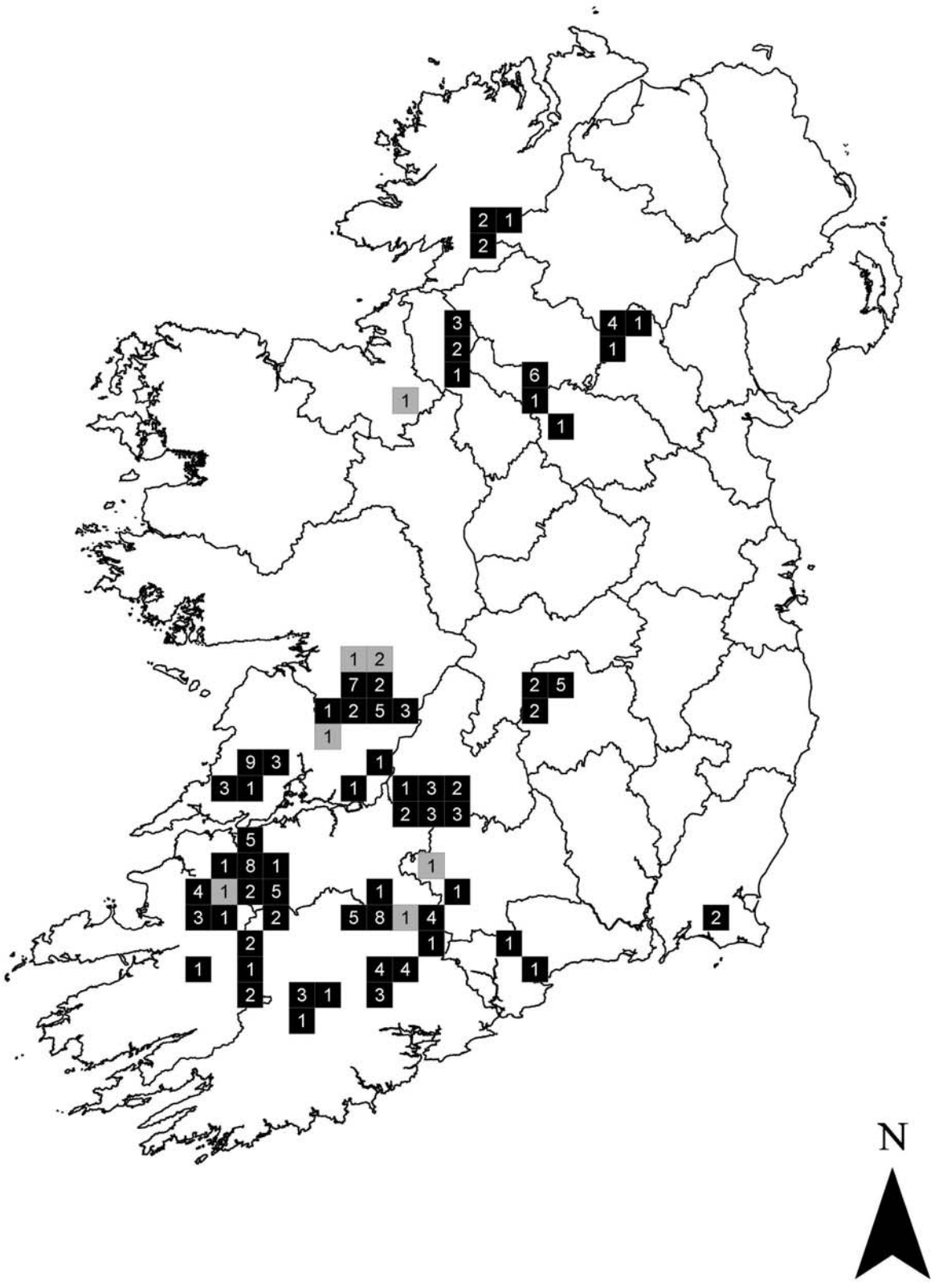

Figure 6. Distribution of 10km squares which contained confirmed and/or possible breeding hen harriers. Each square is labelled with the number of confirmed + possible pairs.

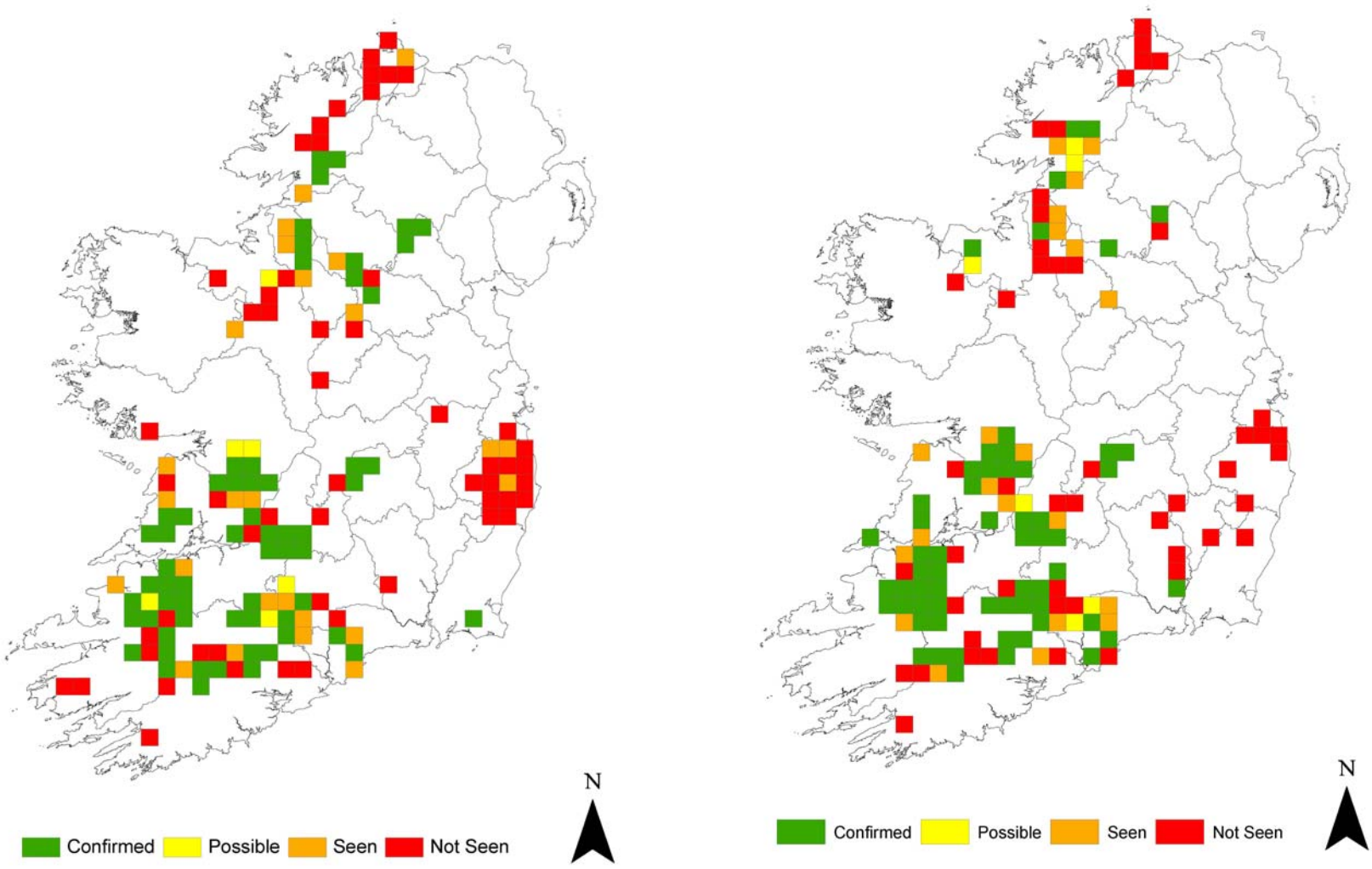

Figure 7. Distribution of breeding hen harriers in 2010 survey (left) compared to 2005 survey (right).

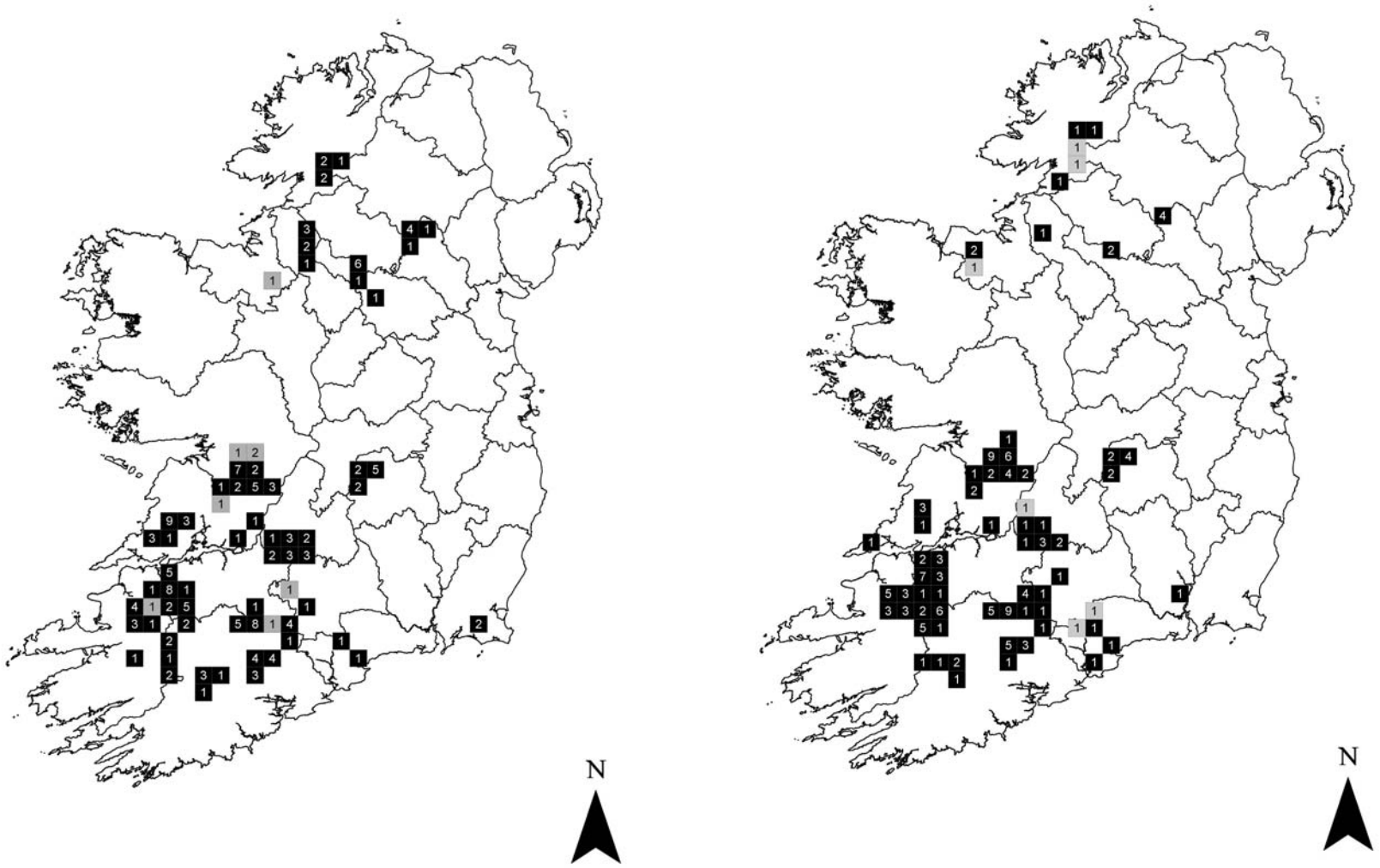

Figure 8. Distribution of confirmed (black) and possible (grey) hen harriers pairs in 2010 survey (left) compared to 2005 survey (right).

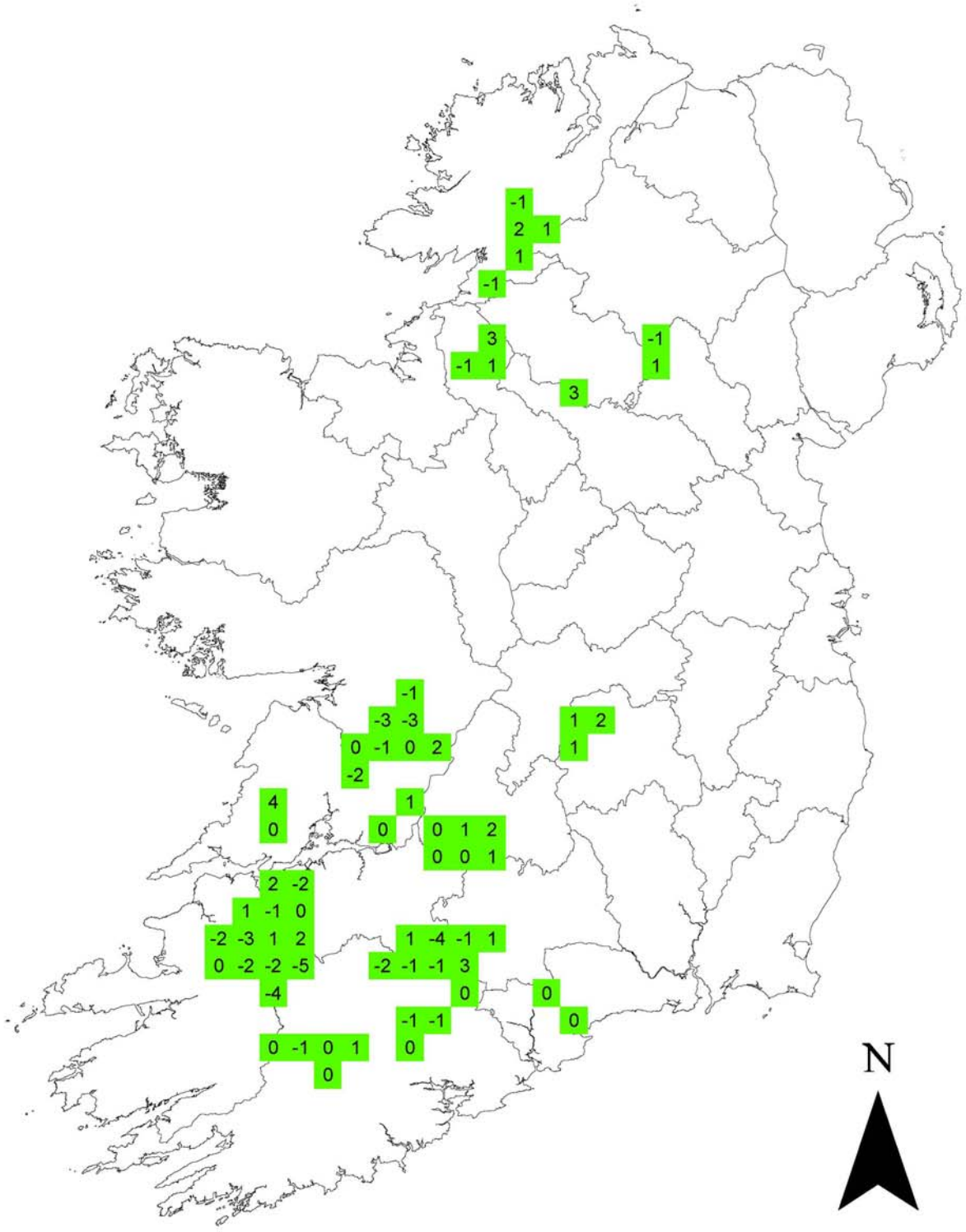

Figure 9. Distribution of 10km squares with confirmed breeding hen harriers surveyed during both 2005 and 2010 national surveys, showing the change in breeding status between years.

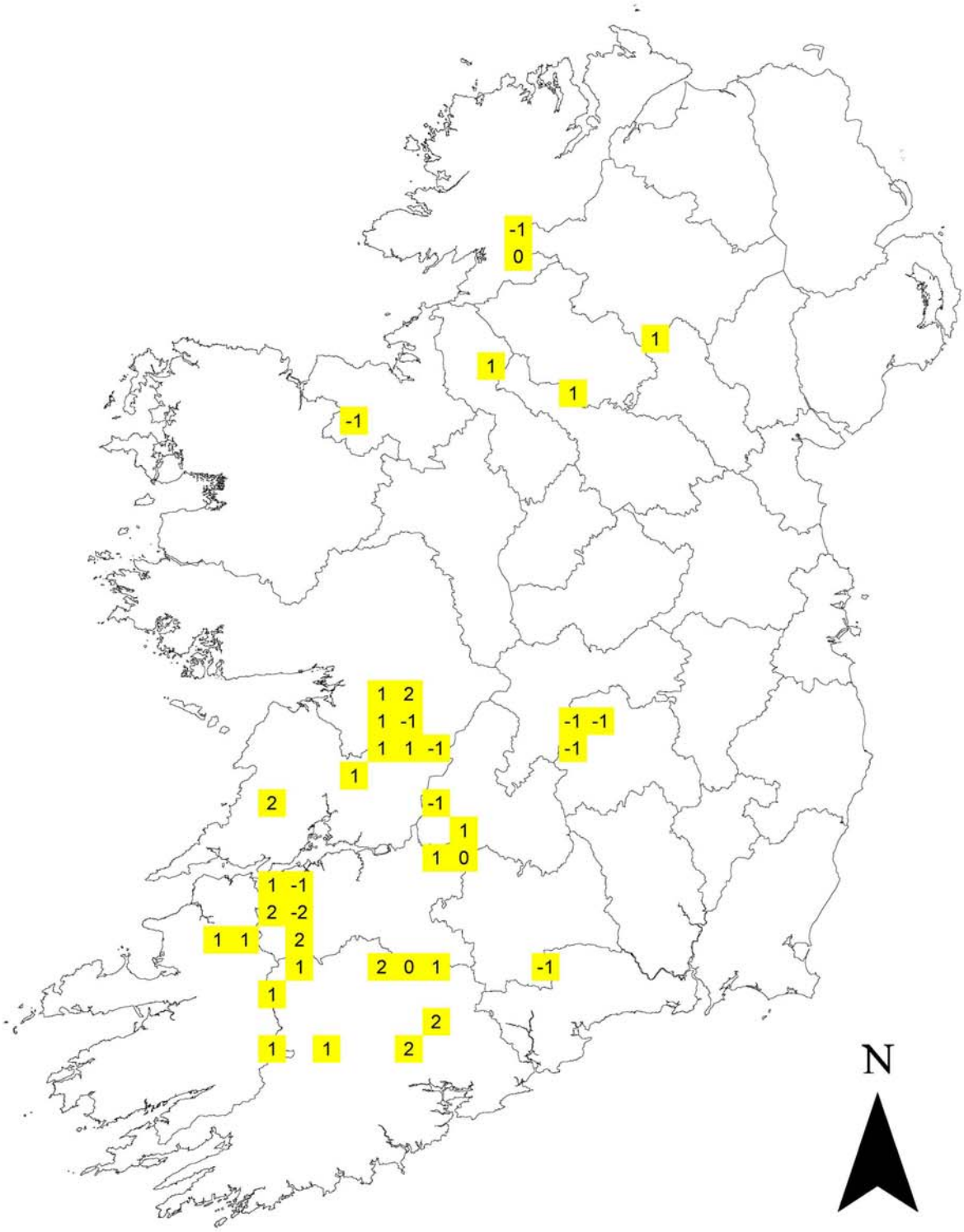

Figure 10. Distribution of 10km squares with possible breeding hen harriers surveyed during both 2005 and 2010 national surveys, showing the change in breeding status between years.

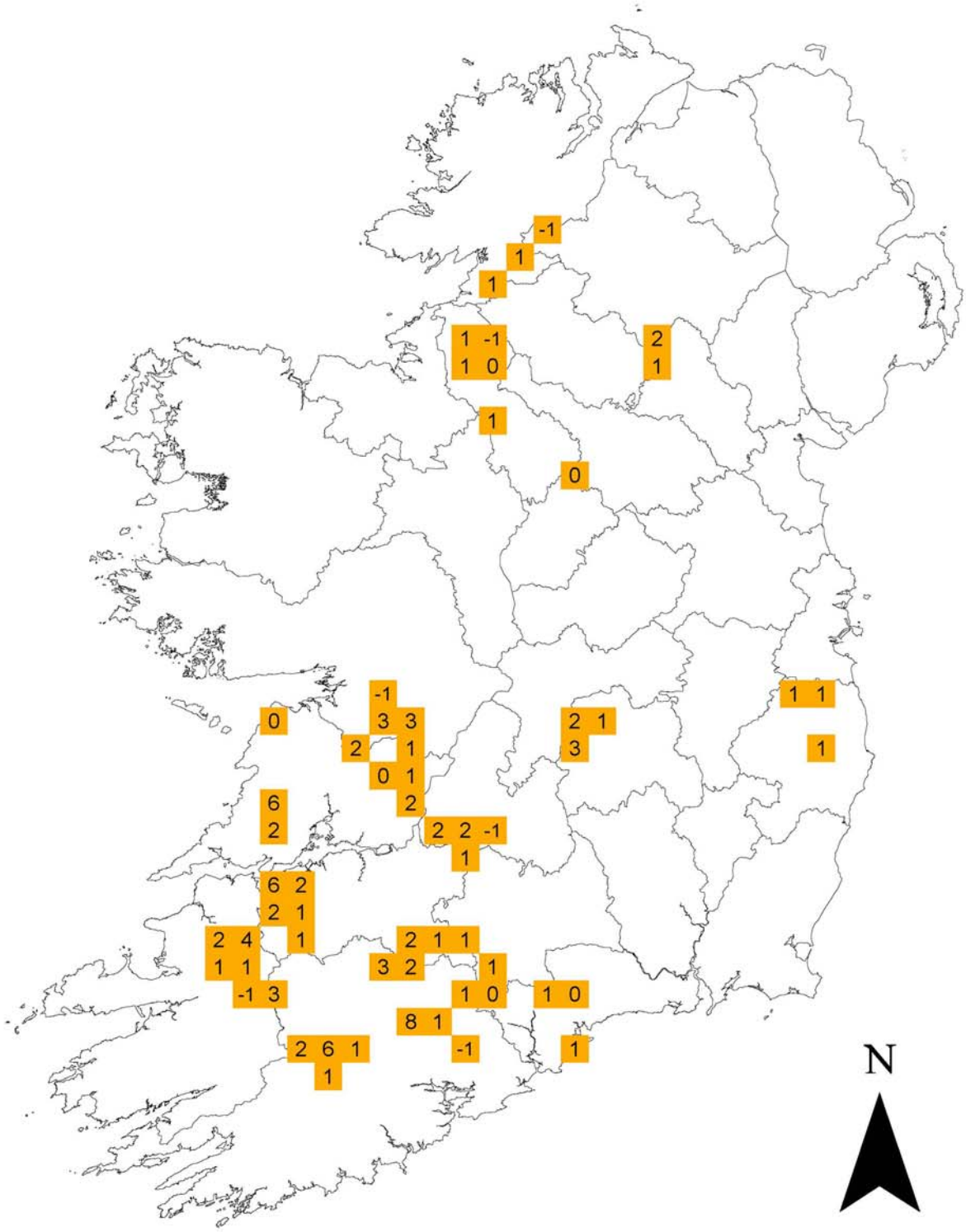

Figure 11. Distribution of hen harriers seen, but not showing breeding behaviour, in 10km squares surveyed during both 2005 and 2010 national surveys, showing the change in status between years.

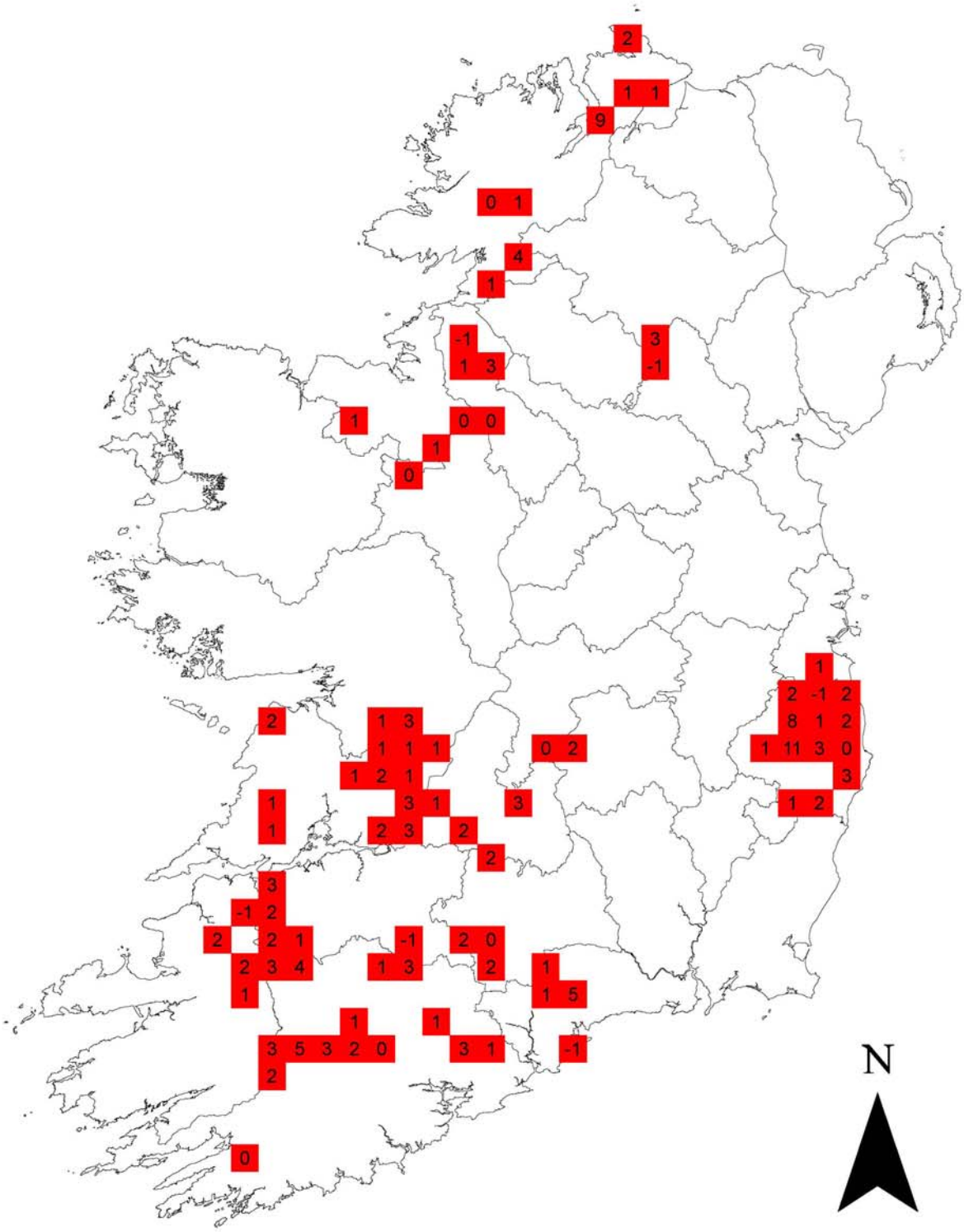

Figure 12. Distribution of 10km squares surveyed during both 2005 and 2010 national surveys, showing the change in breeding status where no hen harriers were seen.

Several of the regional geographical areas defined by Barton *et al.* 2006 exhibited notable population declines since the 2005 survey (Table 13). In particular, declines were recorded in the Stack's / Glanarudderies / Knockanefune / Mullaghareirks / North of Abbeyfeale complex, with an overall loss of nine hen harrier pairs (confirmed + possible) and up to 15 confirmed pairs. Since 2005, declines were also recorded in the Ballyhouras and Slieve Aughties, whilst increases were noted in the Leitrim/ Slieve Rushen area, North & West Clare and Devilsbit / Slievefeelim / Silvermines / King Hill complex. Small increases in the total number of pairs were recorded in the Galtys, Nagles, Boggeraghs / Derrynasaggarts, Slieve Beagh and Slieve Blooms although in most of these areas the number of confirmed pairs declined.

Hen harriers continue to be recorded only in small numbers in the Blue Stacks/ Pettigoe/ South Donegal area, despite extensive suitable breeding habitat (M. Ruddock, personal observation). Confirmed (and possible) breeding records were obtained from Wexford during 2010 for the first time since 1970 (T. Murray, personal communication; see Merne, 1970). The Stack's / Glanarudderies / Knockanefune / Mullaghareirks / North of Abbeyfeale complex retains the largest numbers of breeding pairs but the declines noted are severe. This area held approximately 19.5% of all confirmed breeding hen harrier territories in 2010 (Table 13). Breeding density ranged from zero to eight confirmed pairs per 10km square, with the highest densities in the Slieve Aughties (8), Ballyhouras (7) and Stack's (two squares with 6 territories). Eighteen 10km squares contained three or more confirmed pairs across eight different regions (see * in Table 13). One 10km square in Donegal which borders Northern Ireland held more than three pairs, but only two of these were within the Republic of Ireland.

There were no confirmed or possible breeding pairs on Inishowen; the Ox Mountains; West Cork; Castlecomer / Blackstairs / Kilkenny; the Wicklow Mountains; Kildare or West Kerry despite extensive suitable habitat and either being within the historical range of the species or having recent records of breeding (e.g. Kildare; J. Lusby, personal communication and Inishowen; M. Moloney personal communication).

Table 13. Regional distribution and status of hen harriers within the Republic of Ireland during 2010, 2005 and 1998 – 2000. The regional classifications are as defined in Barton et al., (2006).

Region	Total pairs 1998 - 2000	Confirmed 2005	Possible 2005	Total pairs 2005	Confirmed 2010	Possible 2010	Total pairs 2010
Inishowen Peninsula	1 - 3	0	0	0	0	0	0
Blue Stack Mts, Pettigo Plateau & South Donegal[$]	1	3	2	3 - 5	4	1	4 - 5
Slieve Beagh (Monaghan)*	3	4	0	4	5	1	5 - 6
Leitrim, Slieve Rushen (Cavan)*	0	3	0	3	12	2	12 - 14
Longford, Roscommon	0	0	0	0	0	1	0 - 1
Ox Mountains, Sligo	0 - 1	1	2	1 - 3	0	0	0
North & West Clare*	1 - 2	5	0	5	12	4	12 - 16
Slieve Aughties*	10 - 21	24	3	24 - 27	16	8	16 - 24
Slieve Blooms*	10 - 11	5	3	5 - 8	9	0	9
Slieve Bernagh to Keeper Hill	1	1	1	1 - 2	2	0	2
Devilsbit, Slievefeelim, Silvermines, King Hill	5-9	7	1	7 - 8	11	3	11 - 14
Knockmealdowns, Kilworth	3 - 7	2	2	2 - 4	2	0	2
Ballyhouras*	6 - 8	17	2	17 - 19	10	5	10 - 15
Galtys	0	3	0	3	5	1	5 - 6
Nagles*	3-5	9	0	9	7	4	7 - 11
Boggeraghs, Derrynasaggarts[£]	4-5	5	0	5	6	2	6 - 8
Stack's, Glanarudderies, Knockanefune, Mullaghareirks, North of Abbeyfeale*	38 - 45	40	5	40 - 45	25	11	25 - 36
East Cork & Waterford	0 - 1	2	0	2	1	0	1
West Cork	0	0	0	0	0	0	0
Castlecomer, Blackstairs, Kilkenny	0	1	0	1	0	0	0
Wicklow Mountains	0	0	0	0	0	0	0
Kildare	-	-	-	-	0	0	0
West Kerry	-	-	-	-	0	0	0
Wexford	-	-	-	-	1	1	1 - 2
Total numbers	102-129	132	21	132-153	128	44	128 - 172

[$]indicates a high density areas which contained three (3) or more confirmed territories within at least one 10km (if combined with NI portion of the 10km square)

* indicates high density areas which contained three (3) or more confirmed territories within at least one 10km squares

[£] two pairs classified as confirmed in the Boggeraghs were considered to have been a relocation of a single confirmed pair; but data was provided separately; therefore cautiously a range of 5-7 pairs could be applied

The Northern Ireland survey results for 2010 indicated a 6.3% decline since 2004 (NIRSG & RSPB, unpublished data), despite additional survey coverage, with an estimated 59 territorial pairs; of which 30 were classified as 'proven' and 29 classified as 'probable'. Therefore, the 2010 All-Ireland population is between 158 and 204 territorial pairs which remains within the range of the estimate produced in 2005 (190 – 221 pairs; see Barton *et al.*, 2006), although the declines are evident and the current estimate is higher than lowest range of the 1998 – 2000 estimate (130 – 167 pairs).

3.5 Assessment of population estimates and population changes within SPAs

The hen harrier SPAs encompass 60 10km squares (Figure 13) and in 2010 this subset of 10km squares contained 69 (53.9%) confirmed pairs and 25 (56.8%) possible pairs. During 2005, the same squares contained 85 (62%) confirmed and 13 possible pairs. There was a decline of 18.8% in the numbers of confirmed pairs, a 92.3% increase in the number of possible pairs and a 4.3% decline in confirmed and possible pairs.

Since the SPA boundaries do not cover the entire 10km square areas, digital mapping of territory grid references within the SPA polygons indicates 162 territory records were received from within the existing SPA boundaries. There were 341 territories observed outside the SPA boundaries, four territories recorded within Northern Ireland portions of border 10km squares and four from within the contiguous Northern Ireland Slieve Beagh-Mullaghfad-Lisnaskea SPA. There were 55 confirmed pairs (79.7% of those identified within the relevant 10km squares) and 22 (88%) possible pairs mapped inside the SPA boundaries. Therefore, from the 10km square subset analysis (above) 14 confirmed and three possible pairs were outside existing boundaries within adjacent areas inside the 10km squares. Within the SPAs at least one sighting of a hen harrier was recorded at an additional 48 locations, with no evidence of breeding and no hen harriers were recorded at a further 38 locations.

The combined SPA populations at classification (derived from 2005 survey data) contained 82 to 94 hen harrier pairs and the population has therefore declined overall by 18.1% (Table 14) to a population of between 55 and 77 pairs, although these changes varied regionally (see Table 14).

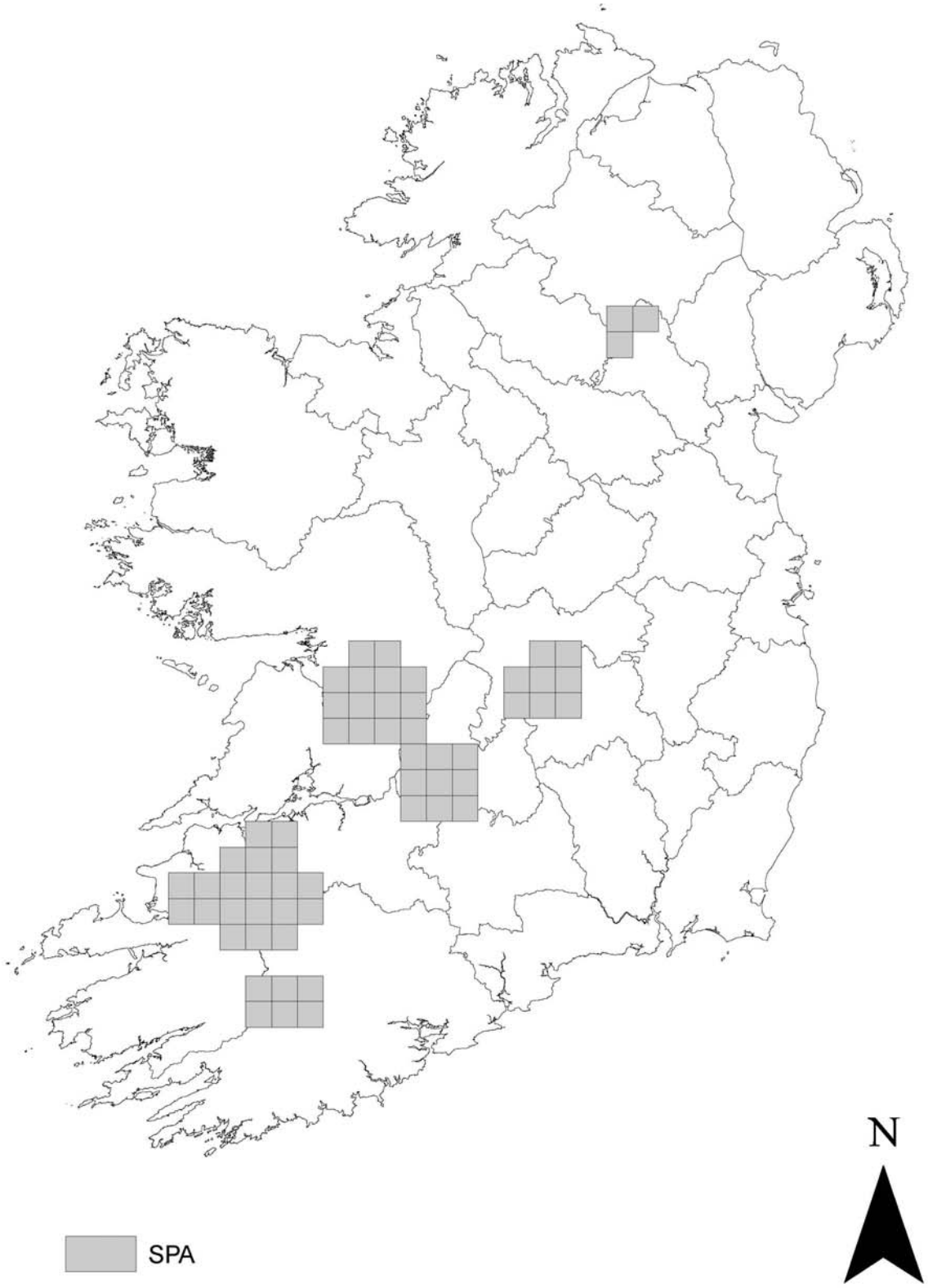

Figure 13. Map showing distribution of 10km squares within which the SPAs are contained.

Table 14. Number of confirmed and possible hen harrier territories within each of the six hen harrier SPAs.

Site Name	SPA Classification Values*				2010 Survey			Change	
	Confirmed	Possible	Confirmed + Possible	%	Confirmed	Possible	Confirmed + Possible	Overall Change	% Change
Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPA (4161)	40	5	45	29	18	11	29	**-16**	-35.6%
Mullaghanish to Musheramore Mountains SPA (4162)	5	-	5	3	2**	1	3	**-2**	-40.0%
Slievefelim to Silvermines Mountains SPA (4165)	4	1	5	3	6	1	7	**2**	40.0%
Slieve Bloom Mountains SPA (4160)	5	3	8	5	9	0	9	**1**	12.5%
Slieve Aughty Mountains SPA (4168)	24	3	27	17	15	8	23	**-4**	-14.8%
Slieve Beagh SPA (4167)	4	-	4	2.5	5	1	6	**2**	50.0%
TOTAL	82	12	94		55	22	77		-18.1%

* The SPA classification (2006) values are based on the 2005 survey figures (Barton et al., 2006) which provided estimates of the hen harrier populations within these sites

** Two independent pairs classified as confirmed during analysis; were later considered to perhaps be derived from the relocation of a single pair; therefore cautiously SPA 4162 could contain only 1-2 pairs and exhibit a severe decline of -60% since classification

3.6 Calculation of breeding outcomes and nest habitat

There were 20 successful breeding attempts recorded within the SPAs, which were confirmed to have fledged at least one young. There were 17 failed breeding attempts and 18 territories at which the breeding outcome was unknown (Table 15). A minimum of 42 young were fledged from within the SPAs. Rates of failure were notably high in some areas, particularly Slieve Beagh SPA (Table 15). The Slieve Blooms on average produced two and half times the number of young per pair as other SPAs. Within the SPAs the majority, 43.6%, of territories confirmed were located in afforested habitats, mainly in second rotation forests, with 36.4% were located in heather moorland (Table 16).

Table 15. Breeding outcome and output within hen harrier SPAs showing number of records and % shown in parentheses.

Site Name	Breeding outcome			Breeding output
	Successful n (%)	Failed n (%)	Unknown n (%)	Young fledged n
Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPA	7 (38.9)	8 (44.4)	3 (16.7)	11
Mullaghanish to Musheramore Mts SPA	-	-	2 (100)	-
Slievefelim to Silvermines Mountains SPA	2 (33.3)	-	4 (66.6)	4
Slieve Bloom Mountains SPA	7 (77.7)	1 (11.1)	1 (11.1)	17
Slieve Aughty Mountains SPA	3 (20)	4 (26.7)	8 (53.3)	8
Slieve Beagh SPA	1 (20)	4 (80)	0 (0)	2
TOTAL	**20**	**17**	**18**	**42**

Table 16. Nest habitat type of confirmed territories within hen harrier SPAs and % shown in parentheses.

Site Name	Habitat type					
	First rotation[1]	Second rotation[2]	Failed forest	Scrub	Heather[3]	Unknown
Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPA	2 (11.1)	7 (38.9)	-	2 (11.1)	6 (33.3)	1 (5.6)
Mullaghanish to Musheramore Mts SPA	-	-	-	-	1 (50.0)	1 (50.0)
Slievefelim to Silvermines Mountains SPA	-	2 (33.3)	1 (16.7)	-	2 (33.3)	1 (16.7)
Slieve Bloom Mountains SPA	-	1 (11.1)	-	-	7 (77.8)	1 (11.1)
Slieve Aughty Mountains SPA	2 (13.3)	7 (46.7)	-	-	1 (6.7)	5 (33.3)
Slieve Beagh SPA	1 (16.7)	1 (16.7)	-	-	3 (60.0)	0
TOTAL	**5 (9.1)**	**18 (32.7)**	**1 (1.8)**	**2 (3.6)**	**20 (36.4)**	**9 (16.4)**

[1] First rotation (1F) includes where categorised as 1F/H; [2] Second rotation (2F) includes where categorised as 2F/S; [3] Heather (H) includes where categorised, at one nest site, as heather/Molinia/Bog myrtle

The majority of confirmed nests/territories were located in afforested habitats (57%), primarily in second rotation crops (43.8%) and more frequently than in open moorland (heather) habitats (23.4%; see Tables 17, 18 & 19).

The breeding outcome was determined at 94 of 128 confirmed territories and breeding was successful at 50 (39.1%); Figure 14; Table 17) whilst 44 (34.4%) were confirmed to fail to fledge any young (Figure 15). A minimum of 104 young fledged from 50 nests during 2010 (i.e. 2.1 young fledged per successful nest; Figure 14). The breeding outcome was unknown at 34 (26.6%) of confirmed territories (Table 18; Figure 16). If it is presumed that all territories classified as possible breeders failed, then the overall failure rate of hen harriers could be greater than 51% of all hen harrier breeding territories.

Breeding was initiated, i.e. at least one egg was laid, at a minimum of 84 (65.6%) confirmed territories and hatching was confirmed at 68 (53.1%) territories. Failure to hatch was proven at 16 territories, and at 44 territories the breeding outcome at hatching was unknown (see Table 18). Fewer young were fledged within the SPAs than outside (see Tables 15 & 18).

Table 17. Nest habitat type and habitat specific breeding success of confirmed hen harrier breeding territories.

Habitat type	Number (n)	Percentage (%)	Breeding success (n & %)
First rotation	12	9.4	5* (41.6)
Second rotation	56	43.8	20** (35.7)
Pre-thicket	2	1.6	***
Failed forest	1	0.8	***
Clearfell	2	1.6	2 (100)
Scrub	8	6.3	5 (62.5)
Heather	30	23.4	16 (53.3)
Unknown	17	13.3	2 (11.8)
TOTAL	128	100%	50

* include one nest identified as 1F/H; ** includes one nest identified as 2F/CF; *** breeding outcome unknown

Disturbance threats to hen harriers and suspected causes of nest failure were reported by fieldworkers at 56 territories (n = 68 individual records). Burning of vegetation was the most frequent (see Table 20). The highest apparent failure rates occur where burning, turf-cutting, vehicular disturbance, forestry operations and/or predation are recorded (Table 20). Records of disturbance at hen harrier territories associated with turf-cutting and windfarm(s) were recorded most frequently in Co. Monaghan and the south-west respectively. There were notably high rates of failure in Co. Monaghan probably resulting directly from human disturbance and land-take associated with turf-cutting.

Predation and/or predation risk was attributed to four species, namely fox (*Vulpes vulpes*), pine marten (*Martes martes*), hooded crow (*Corvus corone cornix*) and mink (*Mustela vison*). One historical nest site (occupied in 2009) was recorded in 2010 to be totally lost due to the construction of power-lines and access road. Amazingly, in 2010, one pair nested within close proximity to a clay pigeon shooting range, but later failed as a result of predation (D. Lyons, personal communication). A similar record occurred within Northern Ireland during 2010 when one pair successfully reared two young within 200m of a clay pigeon shooting range.

Table 18. Breeding parameters of Irish hen harriers during 2010, showing number of sites (n) and percentage (%).

	Stacks etc	Mullaghanish Musheramore	Slieve Felim Silvermines	Slieve Blooms	Slieve Aughties	Slieve Beagh	Inside SPAs	Outside SPAs	Combined
Confirmed	18	2	6	9	15	5	55	73	128
Possible	11	1	1	0	8	1	22	22	44
Clutch initiation (%)	11 (61.1)	1 (50.0)	4 (66.7)	8 (88.9)	7 (46.7)	4 (80.0)	35 (63.6)	49 (67.1)	84 (65.6)
Clutch initiation unknown (%)	7 (38.9)	1 (50.0)	2 (33.3)	1 (11.1)	8 (53.3)	1 (20.0)	20 (36.4)	24 (32.9)	44 (34.4)
Clutch size mean ± se (n)	4.0 ± (1)	-	-	-	4.30 ± 0.88 (3)	-	4.25 ± 0.52	4.13 ± 0.44 (8)	4.17 ± 0.43 (12)
Brood size mean ± se (n)	1 (1)	-	-	-	3.00 ± 0.58 (3)	1 (1)		3.22 ± 0.4 (9)	3.17 ± 0.32 (14)
Hatching confirmed (%)	8 (44.4)	1 (50.0)	4 (66.7)	7 (77.8)	6 (40.0)	2 (40.0)	28 (50.9)	40 (54.8)	68 (53.1)
Failed to hatch (%)	4 (22.2)	-	-	-	1 (6.7)	1 (20.0)	6 (10.9)	10 (13.7)	16 (12.5)
Hatch unknown (%)	6 (33.3)	1 (50.0)	2 (33.3)	2 (22.2)	8 (53.3)	2 (40.0)	21 (38.2)	23 (31.5)	44 (34.4)
Total young fledged	11	-	4	17	8	2	42	62	104
Mean fledged young / confirmed pair	0.61	-	0.67	1.89	0.53	0.4	0.76	0.85	0.81
Mean fledged young / territorial pair (Confirmed + Possible)	0.38	-	0.57	1.89	0.35	0.33	0.55	0.65	0.60
Mean fledged young / successful pair ± se (n)	1.57 ± 0.37 (7)	-	2 (2)	2.43 ± 0.30 (7)	2.67 ± 0.67 (3)	2 (1)	2.10 ± 0.20 (20)	2.07 ± 0.31 (30)	2.08 ± 0.15 (50)
Successful (%)	7 (38.9)	-	2 (33.3)	7 (77.8)	3 (20.0)	1 (20.0)	20 (36.4)	30 (41.1)	50 (39.1)
Failed (%)	8 (44.4)	-	-	1 (11.1)	4 (26.7)	4 (80.0)	17 (30.9)	27 (37.0)	44 (34.4)
Unknown outcome (%)	3 (16.7)	2 (100)	4 (66.7)	1 (11.1)	8 (53.3)	0 (0)	18 (32.7)	16 (21.9)	34 (26.6)

Table 19. Breeding parameters of Irish hen harriers during 2010, separated by habitat type, showing number of sites (n) and percentage (%).

	Stacks etc	Mullaghanish Musheramore	Slieve Felim Silvermines	Slieve Blooms	Slieve Aughties	Slieve Beagh	Inside SPAs	Outside SPAs	Combined
First rotation (1F)	2 (11.1)	-	-	-	2 (13.3)	1 (20.0)	5 (9.1)	7 (9.6)	12 (9.4)
Second rotation (2F)	7 (38.9)	-	2 (33.3)	1 (11.1)	7 (46.7)	1 (20.0)	18 (32.7)	38 (52.1)	56 (43.8)
*Pre-thicket forest (1F or 2F)**	-	-	-	-	-	-	-	2 (2.7)	2 (1.6)
Failed forest	-	-	1 (16.7)	-	-	-	1 (1.8)	0 (0)	1 (0.8)
Clearfell (CF)	-	-	-	-	-	-	-	2 (2.7)	2 (1.6)
Scrub (S)	2 (11.1)	-	-	-	-	-	2 (3.6)	6 (8.2)	8 (6.3)
Heather moorland (H)	6 (33.3)	1 (50.0)	2 (33.3)	7 (77.8)	1 (6.7)	3 (60.0)	20 (36.4)	10 (13.7)	30 (23.4)
Habitat unknown	1 (5.6)	1 (50.0)	1 (16.7)	1 (11.1)	5 (33.3)	0 (0)	9 (16.4)	8 (11.0)	17 (13.3)
Afforested habitats (incl 1F, 2F, CF, failed forest)	9 (50.0)	-	3 (50.0)	1 (11.1)	9 (60.0)	2 (40.0)	24 (43.6)	49 (67.1)	73 (57.0)

** The habitat at two territories was not identified explicitly as 1F or 2F and therefore was classified as 'pre-thicket forest'*

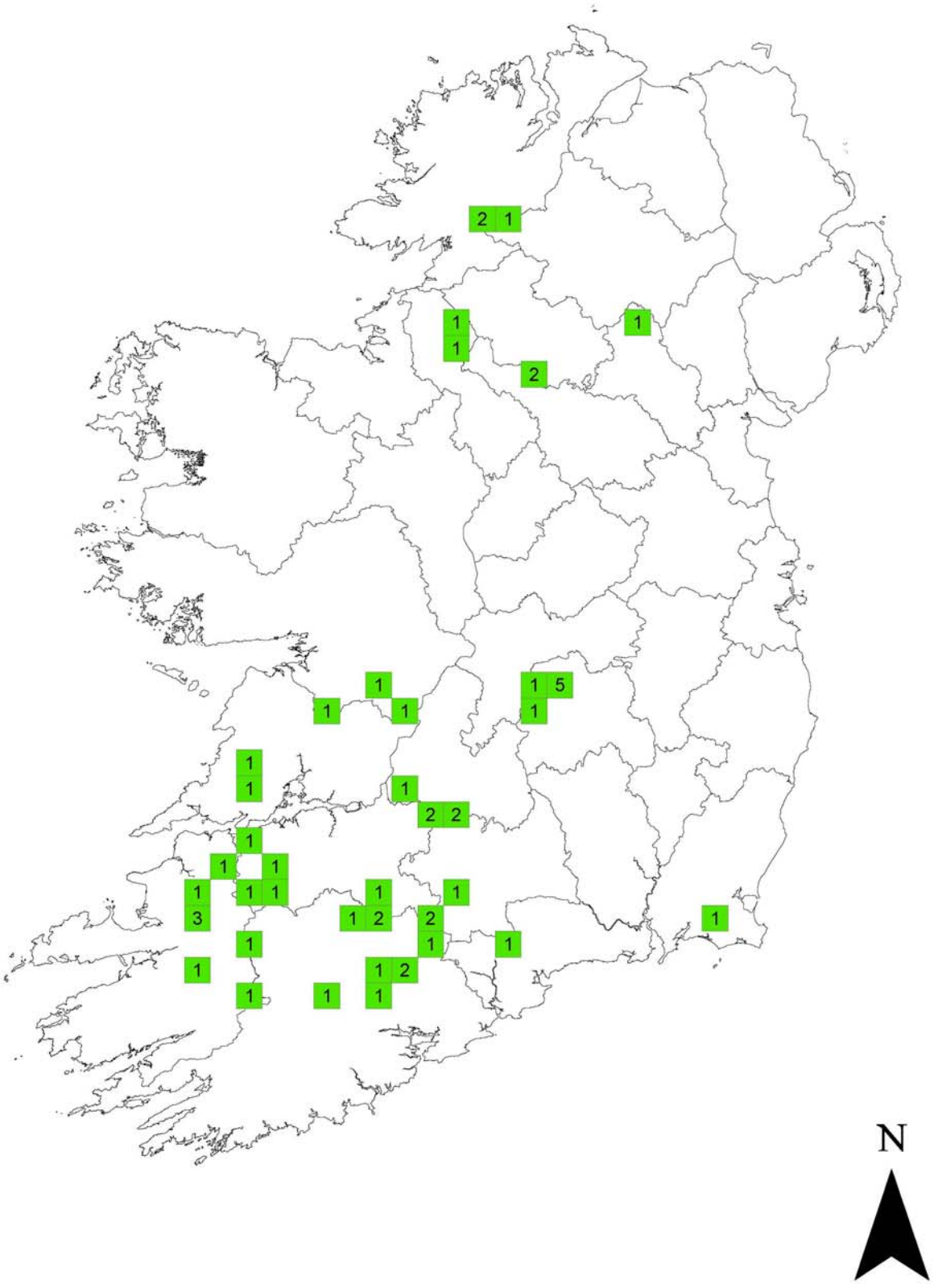

Figure 14. Distribution of 10km squares which contained successful breeding attempts (i.e. fledged at least one young). Each square is labelled with the number of successful nests.

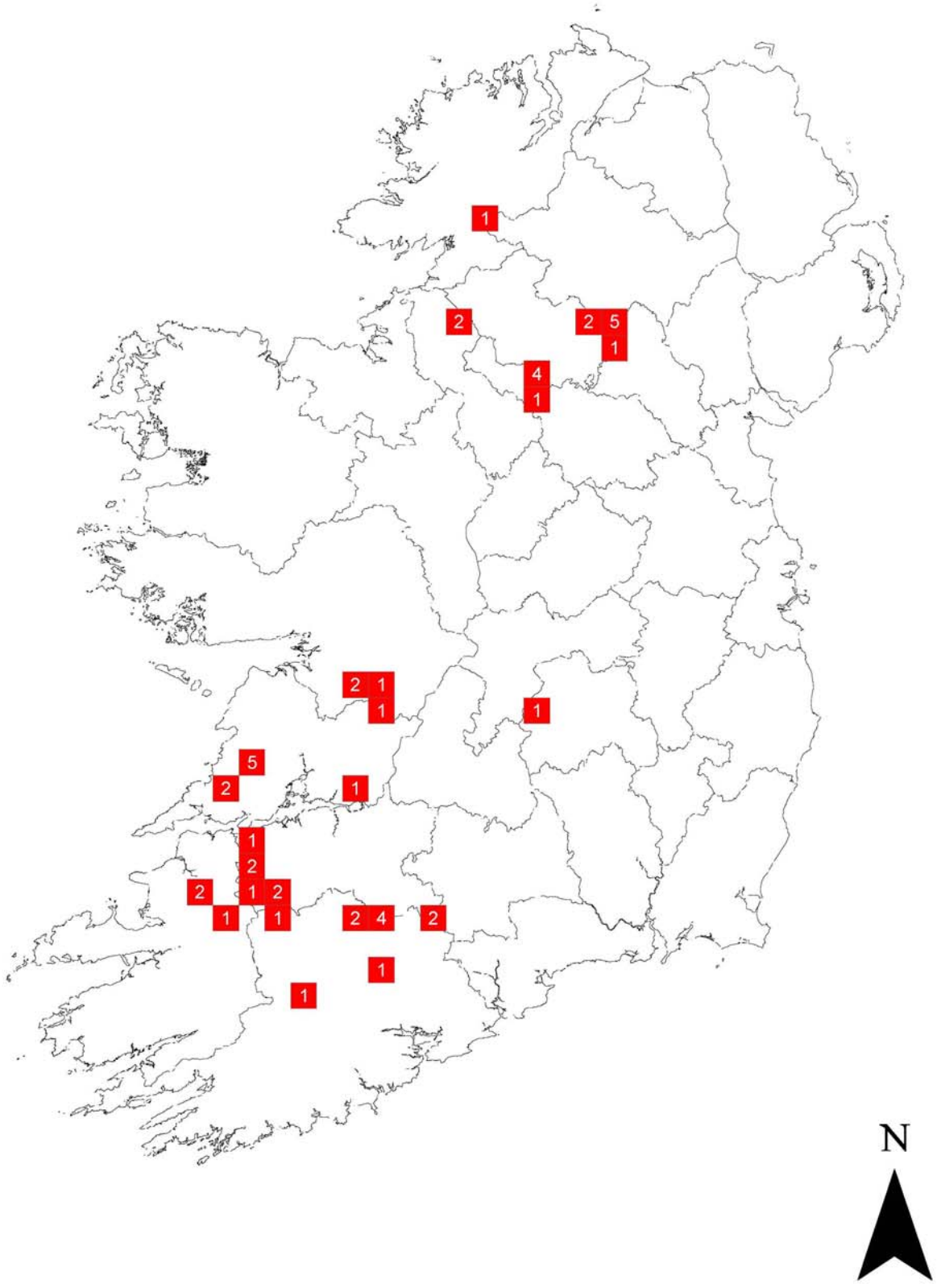

Figure 15. Distribution of 10km squares which contained failed breeding attempts (i.e. fledged no young). Each square is labelled with the number of failed nests.

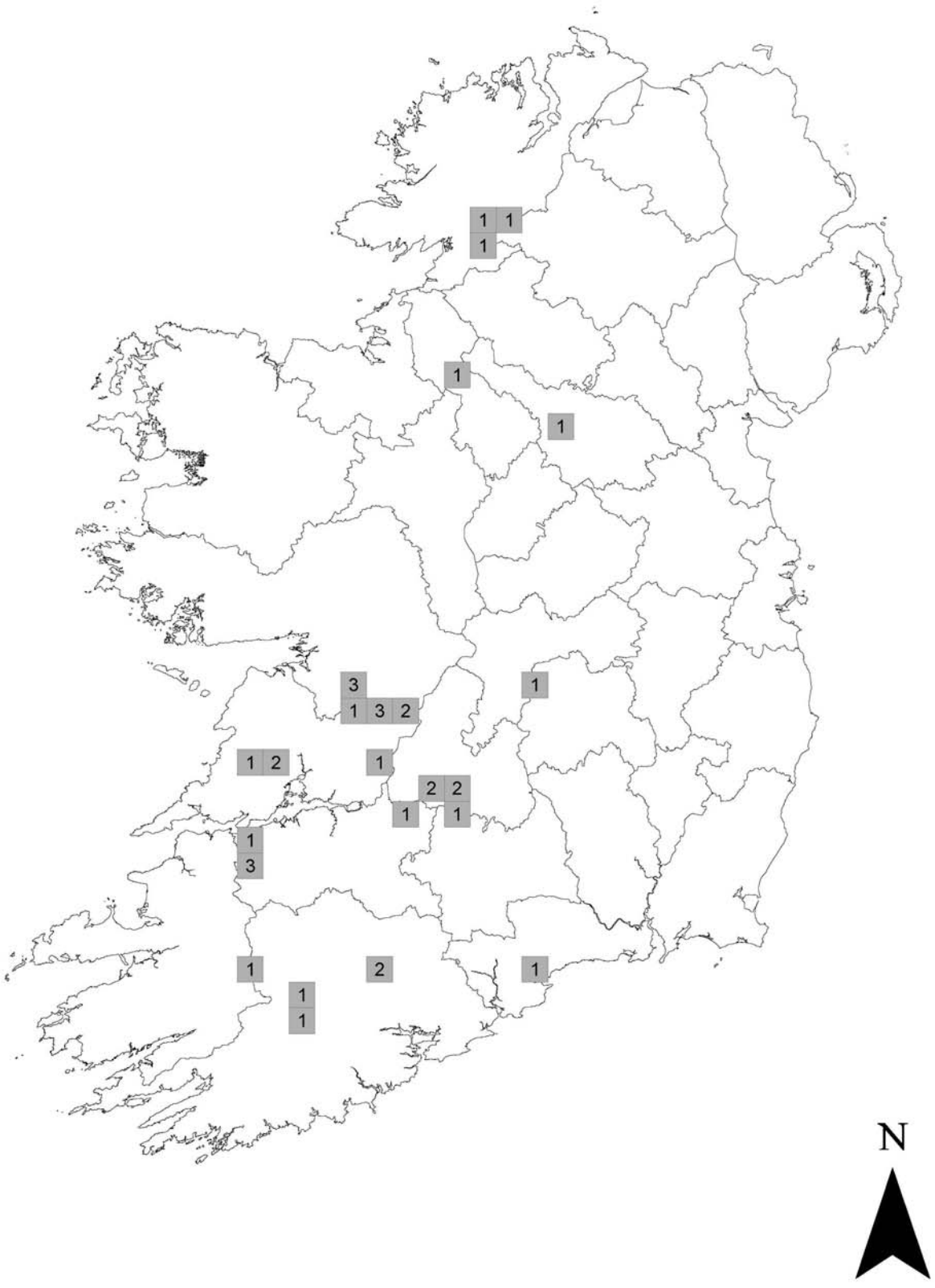

Figure 16. Distribution of 10km squares which contained breeding attempts with unknown outcome. Each square is labelled with the number of nests where the outcome was unknown.

Table 20. Types and occurrence of disturbance and/or suspected reasons for failure reported by fieldworkers at hen harrier territories during 2010.

Activity	Records	Successful	Failed	Possible/Seen	Not occupied*	Counties
Turf cutting	6	1	4	0	1	Monaghan, Tyrone, Kerry
Windfarms	5	0	2	3	0	Cavan, Kerry, Limerick, Cork
Power-lines & roads	1	0	0	0	1	Cork
Vehicles (including scramblers, quarry vehicles, cars)	8	3	2	2	1	Cavan, Kerry, Tipperary, Cork
Burning	15	3	7	1	4	Leitrim, Monaghan, Fermanagh, Tyrone, Kerry, Limerick, Clare, Tipperary
Research activity	5	2	3	0	0	Clare, Cork
Agricultural machinery	3	1	1	1	0	Cavan, Fermanagh
Cattle	2	0	1	1	0	Monaghan, Tyrone
Forestry operations	7	3	3	1	0	Leitrim, Tyrone, Monaghan, Laois, Cork, Limerick
Forest maturation	3	0	0	0	3	Kerry, Limerick
Predation	8	1	6	1	0	Cavan, Kerry, Clare, Limerick, Cork
Scrub clearance	1	0	0	1	0	Cork
Hill walkers	3	0	1	2	0	Tyrone, Tipperary
Clay pigeon range	1	0	1	0	0	Clare

** 'Not occupied' was classified on the basis of data from a traditional territory recorded as having no hen harriers present, during the survey, as a direct result of an area of previously suitable habitat being made unsuitable (i.e. a loss of a territory).*

3.7 Calculation of forest habitat changes between surveys

The area of young forest plantation (≤15 years of age) increased by 7.6% across Ireland between 2005 and 2010 (see Table 21, 22 & 23). The rate of planting/re-planting appears to have marginally increased between these dates across Ireland (Table 23). The area of pre-thicket habitats in the age classes between six and ten years declined between surveys. There was an observed increase in forest maturation i.e. the proportion of the oldest suitable age class (10 – 15 years) and post-thicket stage crop (i.e. >15 years) which increased 29.4% and 21.6% respectively between surveys (Table 23).

There was approximately the same extent of pre-thicket forest (≤ 15 years of age) within the six SPAs although the proportions of the age classes had changed considerably and were variable within the six regions (Tables 24, 25 & 26). The rate of planting has clearly slowed with over 65% decrease in the amount of recent afforestation and/or re-afforestation (Table 26). There are notable declines in the most suitable aged plantation (i.e. age classes 2 – 5 & 6 – 9 years) in all the SPAs with an observed 21% and 9% decrease across all areas in these age classes. The largest declines were recorded in the Slieve Aughties (Table 26). There was an increase in all areas in the post-thicket forest (Table 26), but afforestation was limited within the SPAs in the period between 2005 and 2010 and has decreased annually in all SPAs since 2007 (Table 27).

Table 21. Forest Service & Coillte forest plantation age structure (years) and area (hectares) within Ireland during 2005.

Database/age class	**Area**	**Sub-compartment metrics**		
Coillte Teoranta	**Total (ha)**	**Ave size (ha)**	**Min size (ha)**	**Max size (ha)**
Age class 1	8892.0	3.2	0.1	33.1
Age class 2 – 5	41355.5	4.1	0.1	46.2
Age class 6 – 9	44819.5	4.3	0.1	52.9
Age class 10 – 15	62594.6	4.3	0.1	99.4
Age class >15	258949.9	3.2	0.1	535.5
Forest Service	**Total (ha)**	**Ave size (ha)**	**Min size (ha)**	**Max size (ha)**
Age class 1	9015.6	5.0	0.01	62.0
Age class 2 – 5	47632.4	5.7	0.01	74.9
Age class 6 – 9	46808.7	5.8	0.01	89.3
Age class 10 – 15	48127.2	6.3	0.01	197.9
Age class >15	134608.8	2.8	0.01	603.1

Table 22. Forest Service & Coillte forest plantation age structure (years) and area (hectares) within Ireland during 2010

Database/age class	**Area**	**Sub-compartment metrics**		
Coillte Teoranta	**Total (ha)**	**Ave size (ha)**	**Min size (ha)**	**Max size (ha)**
Age class 1	3529.6	5.1	0.1	39.8
Age class 2 – 5	20176.8	4.4	0.1	32.0
Age class 6 – 9	39438.5	4.0	0.1	45.6
Age class 10 – 15	66032.0	4.3	0.1	99.4
Age class >15	311141.0	3.3	0.1	535.5
Forest Service	**Total (ha)**	**Ave size (ha)**	**Min size (ha)**	**Max size (ha)**
Age class 1	7261.0	3.8	0.003	429.9
Age class 2 – 5	77411.9	3.2	0.002	429.9
Age class 6 – 9	41679.1	5.4	0.001	75.0
Age class 10 – 15	77261.4	6.0	0.001	141.1
Age class >15	167252.3	3.2	0.01	603.1

Table 23. Total area (hectares), age structure and changes of forest plantations within Ireland between 2005 and 2010.

Age Class (years)	**TOTAL 2005**	**TOTAL 2010**	**Percentage change (%)**
Age class 1	17907.6	10790.6	-39.7
Age class 2 – 5	88987.9	97588.7	+9.7
Age class 6 – 9	91628.2	81117.6	-11.5
Age class 10 – 15	110721.8	143293.4	+29.4
<15 years	309245.5	332790.3	+7.6
>15 years	393558.7	478393.3	+21.6

Table 24. Young (pre-thicket) forest plantation (hectares) within each SPA during 2005

Site Name	**Age Class (years)**						
	1	2 – 5	6 – 9	10 – 15	<15	>15	Afforestation (1 – 15)
Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPA	763.9	4624.2	4083.5	5366.5	14738.1	15394.6	8575.5
Mullaghanish to Musheramore Mountains SPA	26.4	195.4	146.4	336.7	704.9	1071.4	209.2
Slievefelim to Silvermines Mountains SPA	248.4	1476.5	1698.3	2136.8	5559.9	6693.4	1986.9
Slieve Bloom Mountains SPA	298.1	1532.9	1402.6	2491.4	5725.0	8911.1	2095.5
Slieve Aughty Mountains SPA	673.7	3644.6	4321.3	5937.2	14576.9	17853.3	3809.9
Slieve Beagh SPA	122.9	354.4	289.1	323.4	1089.9	652.9	190.4
TOTAL	2133.4	11828.0	11941.2	16592.0	42394.7	50576.7	16867.4

Table 25. Age structure of forest plantations (hectares) within each SPA during 2010

Site Name	**Age Class (years)**						
	1	2 – 5	6 – 9	10 – 15	<15	>15	Total afforestation (1 – 15)
Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPA	333.5	4225.7	4069.9	6448.9	15078.0	19613.9	10788.8
Mullaghanish to Musheramore Mountains SPA	5.8	424.0	163.5	268.9	862.2	1343.8	439.4
Slievefelim to Silvermines Mountains SPA	50.3	1006.3	1531.2	2270.7	4858.5	8451.5	2288.9
Slieve Bloom Mountains SPA	41.2	1164.5	1595.1	2247.5	5048.3	10793.6	2086.6
Slieve Aughty Mountains SPA	294.9	2310.7	3055.0	6971.9	12632.6	22403.2	4601.1
Slieve Beagh SPA	10.6	202.8	416.4	412.6	1042.3	913.8	288.9
TOTAL	736.3	9334.0	10831.1	18620.5	39521.9	63519.8	20493.7

Note: Age classes 1-15 includes areas of both re-afforestation and afforestation; and the total area of afforestation is presented separately in the final column

Table 26. Percentage changes in age structure of forest plantations (hectares) within each SPA between 2005 and 2010

Site Name	Percentage (%) change between 2005 & 2010						
	1	2 – 5	6 – 9	10 – 15	<15	>15	Total afforestation (1 – 15)
Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPA	-56.3	-8.6	-0.3	20.2	2.3	27.4	25.8
Mullaghanish to Musheramore Mountains SPA	-78.0	117.0	11.7	-20.1	22.3	25.4	110.0
Slievefelim to Silvermines Mountains SPA	-79.8	-31.8	-9.8	6.3	-12.6	26.3	15.2
Slieve Bloom Mountains SPA	-86.2	-24.0	13.7	-9.8	-11.8	21.1	-0.4
Slieve Aughty Mountains SPA	-56.2	-36.6	-29.3	17.4	-13.3	25.5	20.8
Slieve Beagh SPA	-91.4	-42.8	44.0	27.6	-4.4	40.0	51.7
TOTAL	-65.5	-21.1	-9.3	12.2	-6.8	25.6	21.5

Note: Age classes 1-15 include areas of both re-afforestation and afforestation; and the total area of afforestation is presented separately in the final column.

Table 27. Afforestation (hectares) within each SPA between 2005 and 2010.*

Site Name	Year					
	2005	2006	2007	2008	2009	TOTAL
Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPA	406.3	2578.1	298.2	205.9	146.8	3635.3
Mullaghanish to Musheramore Mountains SPA	27.0	90.5	59.7	74.9	5.8	257.9
Slievefelim to Silvermines Mountains SPA	136.9	419.5	109.6	74.7	50.3	791.0
Slieve Bloom Mountains SPA	28.2	411.3	69.9	51.3	4.1	564.8
Slieve Aughty Mountains SPA	147.2	937.5	139.6	125.5	124.4	1474.2
Slieve Beagh SPA	6.9	145.0	22.0	0.0	0.0	173.9

* Afforestation estimates presented here are derived from multiple data sources and do not reflect annual granting of planting permissions.

4.0 Discussion

4.1. Survey implementation, coverage and data submission

Given the dispersed and large-scale nature of the hen harrier survey, it was necessary to deploy large numbers of fieldworkers to ensure adequate coverage. The work-shops aimed to standardise both methods and experience of the surveyors (Bird & Bildstein, 2007; Hardey *et al.*, 2006; 2009) and were well attended. Over 230 10km squares were identified as containing breeding hen harriers and/or suitable breeding habitat; it was necessary to prioritise squares for coverage matched with fieldworker availability and geographic locations (see Hager & Brudney, 2008; 2010) and effort maintained via internet communication (Hart, 2002). Whilst the database of previous participants and general raptor surveyors in Ireland is large (>400 people); a total of 126 (~30% of those invited) participated in the survey. A total of 149 10km squares were covered, although some deviation from initial priority allocation was recorded. However, coverage was greater than 80% of initial allocated squares, except for lowest priority ('red') squares (~71%). This may be an artefact from fieldworkers that were aware that 'red squares' had no recently recorded hen harriers; but contained suitable habitat and hence may have surveyed away from areas which may have yielded negative observations (see Sim *et al.*, 2007). Similarly of all the squares identified for the survey, coverage was highest for priority one ('green') squares and declined to less than 52% for other priority squares. Overall coverage was lowest for least priority 'red' squares (33%). It is important, in all raptor surveys, to survey all areas of suitable habitats using the same methodology and without regards for historical records, in order to ensure i) comparability between surveys; ii) detection of range expansion/re-colonisation and iii) detection of movement between years from adjacent areas (Hardey *et al.*, 2006; 2009) and iv) provide robust estimates of population change (Greenwood *et al.*, 2003).

A large, dispersed, multi-participant project, such as this one, generates a vast quantity of data for interpretation. There were some delays in the acquisition and standardisation of raw data submissions. Data were submitted in various formats (e.g. emails, data sheets and verbal communications) which required to be standardised before analysis and should be addressed in future surveys. Specifically this should be targeted at i) improving the integration of information technology in the submission of data by volunteers (Hackler & Saxton, 2007) since the uptake of the online data reporting forms (see www.goldeneagle.ie) was low and ii) the standardisation of data formats. The latter creates difficulties in the visual interpretation of territorial data; complicates the comparison with previous survey data and creates difficulties in the digitisation of spatial data points. In particular the selection of a name(s) for the site and/or area of suitable habitat being observed by fieldworkers require to be standardised in future surveys; especially where multiple surveyors are involved and/or to assist future fieldworkers in subsequent surveys. Whilst grid references, for nests, may remain consistent between years; perhaps less so for transient hen harrier nests in forests; the disparity in selection of a site name can make analysis between years complicated and duplicative (P. Hawarth, personal communication).

The commitment to surveys, support for the project and willing provision of hen harrier nest data by volunteer fieldworkers, hen harrier researchers, governmental staff, non-governmental staff and commercial fieldworkers involved in baseline surveys for windfarm developments was exemplary and their involvement should be maintained and encouraged in future monitoring work.

4.2 Survey effort and observations

The surveyors completed a minimum of over 2000 vantage points amounting to 4085 hours in field work; which is over double the effort compared to 2005 (2006 hours; 983 vantage points). Summary data received for some areas during 2010 undoubtedly required several hundred hours of observation and these vantage point data were therefore under-represented. Hen harriers require intensive fieldwork to locate nests. In particular field visits during the early part of the breeding season (e.g. March and early April) can reduce the amount of effort required in later visits once indicative breeding areas are identified (Hardey *et al.,* 2009; O'Donoghue, 2011). The completion of first visits was similar in 2010 (58.7%) to the 2005 survey effort (59.8%); whilst second visits were undertaken slightly more during 2010 (80.6%) than 2005 (76.1%) but fewer final visits were undertaken during 2010 (53.6%) than 2005 (67.1%). The addition of another visit for fieldworkers during 2010 may have divided effort for final visits, but it remains important to collect robust data from all times during the breeding season. Importantly the incomplete occurrence of first visits (in both recent surveys) may lead to fewer territories being identified, or poor detection of breeding attempts which fail early and it will be important in future surveys to maximise the number of visits in the early breeding season (see Sim *et al.,* 2004). Notably a breeding pair was more likely to be classified as a confirmed pair than a possible pair when the percentages of first visit were higher in both national surveys. This equates to 71.9% (2010) & 72.0% (2005) first visits completed for confirmed pairs and 65.9% (2010) and 38% (2005) for possible pairs respectively.

4.3 Other research

The value of additional recording is shown by the extensive maps of other species; thereby adding value to the data already being collected on a suite of other species. It is unlikely to form part of a comprehensive survey for any of the detected species as it is likely that many people did not submit all sightings. However, with such large numbers of people and the hours being completed in fieldwork; the value of additional records for rare (e.g. red-footed falcon) and/or under-recorded raptor species (e.g. goshawk or merlin) is high and will help inform future management and/or other surveys (e.g. Bird Atlas 2007 – 2011).

Few wing-tag sightings were recorded (n = 4), one of which was a juvenile tagged during 2010. This low number of sightings may be indicative of a small proportion of these tagged individual entering the breeding population as result low survival rates between years or emigration from the current study area (Etheridge & Summers, 2006; B. O'Donoghue & M. Wilson, personal communication). 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.,* in prep; M. Wilson, personal communication).

There were few post-fledging nest visits and/or feather and prey collections, but again such wide-ranging fieldwork can assist in the collection of additional data provided fieldworkers allocate sufficient time to the collection of data. Equally fewer areas should perhaps be monitored by each individual fieldworker thereby providing time for the collection of additional data. Future surveys should be mindful of limiting resources to collect these additional data and task should not be considered onerous by the fieldworkers.

4.4 Analysis of population estimates, population change and breeding density

The number of breeding pairs of hen harriers found during this survey is similar to that found by the last national survey in 2005 despite over twice the field effort recorded during 2010. The overall number of confirmed breeding pairs has decreased marginally (132 to 128), but the number of possible breeding pairs has apparently increased (21 to 44 pairs). Whilst it is conceivable that the population remains comparatively stable, the increase in field effort means that a larger number of 'extra' pairs may have been located during 2010. This raises the possibility that there has actually been a decrease between the two surveys.

The allocation of squares, whilst not random, was stratified to cover priority areas and ensure comparability with previous surveys. In particular, additional survey effort during 2010 resulted in differential coverage of some areas between the 2005 and 2010 surveys, hence the requirement for a sub-set analysis to increase comparability. There was a 96% increase in effort in the sub-set of squares surveyed during both 2010 and 2005 (3770h & 1923h respectively). Therefore it is reasonable to expect that more hen harriers would have been detected in this sub-set analysis. This highlights a real difficultly in assessing the population change between years and the decline in the previously recorded range (Norriss *et al.,* 2000; Barton *et al.,* 2006) may therefore be larger than the 6.4% evidenced in the present study. The apparent increase in possible breeding pairs in the sub-set analysis may reflect the increased survey effort. Furthermore this could also be indicative of a decrease in breeding success, since breeding attempts that fail early on are more likely to be recorded as 'possible' than successful breeding attempts.

The breeding range of confirmed pairs has remained within approximately the same number of 10km squares (53 squares) since 2005 although these differed between survey years. Areas where losses of breeding pairs appear to have been particularly severe include the Stack's / Glanarudderies / Knockanefune / Mullaghareirks / North of Abbeyfeale complex and the Slieve Aughties. Contiguous squares in these areas exhibit considerable losses of breeding pairs since the previous national survey (Figures 9 & 10), which are confirmed by the findings of more detailed studies in each of these areas (O'Donoghue, 2010; Wilson *et al.,* 2012). However, the reasons for these 'clumped' declines remain unclear. The role of habitat changes (see Section 3.7); such as forest maturation (Irwin *et al.,* 2008; Wilson *et al.,* 2009); constrained breeding success (Irwin *et al.,* 2008; Ruddock *et al.,* 2008; O'Donoghue, 2010); disturbance (Whitfield *et al.,* 2008); prey availability; displacement by wind-farms (Madden & Porter, 2007; Ruddock & Reid, 2010; O'Donoghue *et al.,* 2011) and/or disturbance and land management or loss of open moorland habitats (Ruddock *et al.,* 2008; O'Donoghue, 2010) require further investigation in these areas.

Forest maturation, may be partly responsible for regional decreases in breeding hen harriers, as a shift in age structure of plantations was recorded between the two surveys with a general increase in older classes of suitable forest breeding habitats (Table 23). Notably, whilst the proportion of older plantation increased considerably in the Stack's Complex, the lowest decline in availability of 2 – 5 and 6 – 9 age classes was recorded (see Table 26). A decrease in the availability of suitable breeding (i.e. nesting and foraging) habitat may therefore have contributed to decline of the hen harrier population in this area. Unregulated, unmanaged burning in particular can have extreme consequences on loss of suitable hen harrier habitat and fieldworkers reported multiple occurrences of heather burning during surveys (see Table 20).

In Britain, notably Scotland, where the species comes into conflict with management for red grouse, hen harriers are heavily persecuted, such that their populations are limited by illegal killing (Etheridge *et al.,* 1997; Whitfield *et al.,* 2008; Redpath *et al.,* 2010; Fielding *et al.,* 2009; 2011). Confirmed cases of hen harrier persecution in Ireland are rare (O'Donoghue, 2011; IRSG unpublished data). Anecdotal evidence indicates that this may be occurring directly (e.g. shooting) or indirectly (e.g. burning of suitable nest habitat; see also Ewing *et al.,* 2011) and it is therefore unclear of the population effects at a regional or national scale, if any. Spatial data on these incidences, even where anecdotal, would increase the understanding of this problem (Real *et al.,* 2001; Whitfield *et al.,* 2004a; b).

The apparent increases recorded in Leitrim / Slieve Rushen, North & West Clare and the Devilsbit / Slievefeelim / Silvermines / King Hill complex are undoubtedly a result of an increase in fieldwork effort by hen harrier researchers (see also Irwin *et al.,* 2008) and the contribution of data by commercial consultants operating in these areas during 2010. Further effort in the Blue Stacks / Pettigoe and south Donegal and Ox Mountains would yield a greater understanding of hen harrier numbers and distribution in these areas (B. Porter, personal communication; M. Ruddock, personal observation); as field effort has been typically low during all national surveys (Barton *et al.,* 2006). Dedicated effort during 2010 in south Donegal located five previously unrecorded pairs (two pairs in Donegal; and three pairs immediately adjacent in Northern Ireland).

Again, despite extensive suitable breeding habitat and historical prevalence only small numbers of hen harriers continue to be seen in Wicklow (see also Norriss *et al.,* 2002; Barton *et al.,* 2006); but no confirmed or possible breeding was recorded during 2010 despite early presence of adults and sightings of fledged juveniles in August (D. Clarke, personal communication). Recent insights provided by satellite telemetry (IRSG & Golden Eagle Trust, 2009) have revealed rapid immigration of hen harriers to Wicklow from elsewhere (Knockmealdowns; 153km away from the nest location by the 19th August) and serve as a caution against over-interpreting late season sightings of juveniles in suitable breeding habitat.

A 6% decline in the breeding population of hen harriers was also documented in Northern Ireland, and the All-Ireland population of hen harriers in 2010 (158 to 205 pairs) is similar to that found in the previous national survey(s). Additional survey effort was undertaken in both jurisdictions during 2010 (this study; NIRSG unpublished data) and higher numbers of pairs should have been located if the actual number of breeding pairs was stable between the two survey periods. Suitable breeding habitat throughout Britain remains unoccupied by hen harriers and preliminary analyses in Ireland suggest a similar scenario (Fielding *et al.,* 2009; 2011). The recent down-grading of the conservation status of hen harriers in Ireland from red to amber (Newton *et al.,* 1999; Lynas *et al.,* 2008) was based on an apparent population increase between 2000 and 2005 (Norriss *et al.,* 2002; Barton *et al.,* 2006). Future assessment of priority species conservation status should take into consideration the variation in survey effort in the derivation of population estimates, particularly for hen harriers given the extent of the regional declines recorded during 2010. Despite the evidence of population increases in some areas and the difficulties in assessing changes between years and we would advise against continued de-prioritisation for this species, at least in the short-term. The hen harrier remains highly vulnerable to persecution (Green & Etheridge, 1999; Fielding *et al.,* 2009) and habitat change (Watson, 1977; Redpath *et al.,* 1998; Thirgood *et al.,* 2000; Tapia *et al.,* 2004). In particular, both the quality and quantity of foraging habitats influence hen harrier distribution (Watson, 1977; Pain *et al.,* 1997; Redpath & Thirgood, 1999; Redpath *et al.,* 2002a; b; Madders 2003); foraging success (Madders; 2000) and

demographic parameters such as clutch size and fledging success (Madders, 2000; Madders, 2003; Redpath *et al.*, 2002; Thirgood *et al.*, 2002; 2003; 2006; Amar *et al.*, 2004).

4.5 Analysis of population estimates and population changes within SPAs

Important hen harrier populations in three of the six SPAs have declined by 14.8%; 35.6%; and 40% and the combined population protected within the SPAs has decreased overall by 18.1%. The largest and most severe change is noted from the small population in Mullaghanish to Mushermore (Site Code: 4162; Table 14) and then two other SPAs with large declines, the Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPAs and the Slieve Aughties (Site Code: 4161 & Site Code: 4168; Table 14). These latter sites are in the two areas of largest regional declines; namely the Slieve Aughties and the Stack's / Glanarudderies / Knockanefune / Mullaghareirks / North of Abbeyfeale complex. The hen harriers in these two SPAs exhibited greatest preference for forest nesting than hen harriers in other SPAs (Tables 16 & 19) and are therefore most likely to be affected by changes in the forest age structure and/or variation in breeding success associated with forest habitats (see also Wilson et al., 2010; O'Donoghue, 2010). There has been a decrease in the forest age-classes suitable for hen harrier nesting and a decline in afforestation across all the SPAs (Table 26) which may have affected distribution. Afforestation in all SPA areas appears to have dramatically increased during 2006 (Table 27), immediately prior to SPA designation in 2007 and has since declined annually. The quality of open habitats for hen harriers may need to be improved in order to compensate for decreased availability of young forest habitats due to the changing age profile of forest plantations in these areas. Maximising the value of forested areas for hen harriers in Ireland, particularly in SPAs, therefore requires careful planning to integrate suitable hen harrier nest locations in close proximity to a mosaic of suitable foraging habitats (see also Ruddock et al., 2008; Wilson et al., 2005; 2006; Wilson et al., 2009; 2010; O'Donoghue et al., 2011).

The hen harrier populations in the Slieve Beagh and Slieve Blooms SPAs both appeared to have increased substantially and these areas also contain the highest proportion of heather nesting hen harriers (Table 16). Hen harriers in the Slieve Blooms experienced particularly high levels of breeding success and fledged a large number of young, but those in Slieve Beagh were much less successful. The former is considered to be highly variable between years (J. Monaghan, personal communication) and the latter may be due to high levels of disturbance and mechanised turf-cutting in close proximity to remnant areas of suitable habitat in which the Slieve Beagh harriers are nesting (C. McGeough & M. Ruddock, personal observation) a situation which also applies to the contiguous Northern Ireland Slieve Beagh – Mullaghfad – Lisnaskea SPA.

The driver(s) for population change in all these areas are likely to be varied and complex; but the declines in some areas requires particular investigation of the roles of disturbance and habitat suitability which are likely to strongly influence population parameters (Newton, 1979; 1998). Where hen harrier populations are heavily dependent on afforested habitats for nesting and/or foraging it is likely that changes to forest structure have the potential to be detrimental to hen harriers. Forested landscapes that support breeding hen harriers should therefore be managed to ensure the continued provision of both suitable nesting habitat and high quality, prey-rich, foraging habitat. At least in some situations, hen harriers nesting in some forest habitats may experience lower breeding success

than those in other habitats (Ruddock *et al.,* 2008; Wilson *et al.,* 2010; O'Donoghue, 2010). Although hen harriers in Ireland nest more frequently in afforested habitat (Norriss *et al.,* 2002; Barton *et al.,* 2006; Wilson *et al.,* 2009; this study) their foraging activity is biased towards open moorland (Table 9; Barton *et al.,* 2006) and diet is predominantly comprised of open moorland passerines (Scott, 2005; O'Donoghue, 2010) and small mammals (O'Donoghue, 2010). Future management in Ireland should also be directed towards improving the quality and quantity of foraging, particularly natural or semi-natural habitats (Arroyo *et al.,* 2009; Robinson, 2010; O'Donoghue, 2001) and/or open nesting habitats (Smith *et al.,* 2001; Ruddock *et al.,* 2008; O'Donoghue, 2010). There is an increasing occurrence of introduced small mammal species (O'Donoghue, 2010) which has also been recorded in other raptor species (Tosh *et al.,* 2008; Grant, 2009; Lusby *et al.,* 2009).

4.6 Analysis of breeding outcomes and nest habitat

Breeding success varied considerably between different areas, but this variation is difficult to interpret especially as hen harrier breeding parameters can vary considerably between years (Irwin *et al.,* 2008; Wilson *et al.,* 2012). It is conceivable that all of the 34.4% of confirmed breeding pairs identified in this survey for which breeding initiation was not confirmed (Table 18) failed to breed. This would make estimates of failure to initiate breeding similar to those found by other Irish research (34.6%; O'Donoghue, 2010) and to research in Orkney (Amar *et al.* 2003, 25% of male and 52% of females) and higher than was found in Langholm (Amar *et al.,* 2003; 12% of males and 0% of females). If all possible breeding pairs also did not attempt to breed this would increase the non-breeding rate to 51.2% which is similar to Orkney (51%). Mean fledging success in the present study (39%) is similar to that reported in the last national survey for the Republic of Ireland (43.9%, Barton *et al.,* 2006) and a long-term intensive study in a subset of (37.5%, Wilson *et al.,* 2012) although is lower than other estimates (77-82%, Norriss *et al.,* 2002; 60%, Irwin *et al.,* 2008; 65%, O'Donoghue, 2010) from the same region. Estimates, found here are also lower than Scotland which ranges between 52% and 76% (Picozzi, 1984; Meek *et al.,* 1998; Redpath *et al.,* 2002; Amar *et al.,* 2003; 2005; 2007) and the Welsh population (33-60%). Low estimates of this parameter have been linked to population declines and/or the effects of 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).

In a small sample size; clutch size was a mean of 4.1 eggs and similar to that found recently in Ireland (4.1 eggs, Irwin *et al.,* 2008; 3.9 eggs, O'Donoghue, 2010); but is lower than clutch sizes from other regions in Britain, e.g. Scotland (4.4 – 6.0 eggs, Green & Etheridge, 1999; 4.1 – 5.2, Redpath *et al.,* 2002), Orkney (4.6 eggs, Amar *et al.,* 2003), Langholm (5.0 eggs, Amar *et al.,* 2003, Redpath *et al.,* 2001) and Wales (4.7 eggs, Whitfield *et al.* 2008). Ruddock *et al.,* (2008) and Scott & Clarke (2008) report lower mean values (3.5 & 3.6 eggs respectively) for hen harrier clutches in Northern Ireland. It is possible that the lower clutch sizes observed in Ireland generally are the result of scarcer or less profitable food resources which may be further constrained in Northern Ireland. However, more information on abundance and availability of different prey-types is necessary in order to test this (see O'Donoghue, 2010). In addition, the total mean numbers of fledglings recorded (0.81 young) were comparable to mean estimates from Northern Ireland (0.87, Ruddock *et al.,* 2008) and Orkney (0.82 young, Redpath *et al.,* 2002; 0.68, Amar *et al.,* 2007) and lower than elsewhere in Scotland (range 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 a higher number of fledglings 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).

The low rates of polygyny observed (<1%) may be indicative of poor pre-breeding food supply (Altenburg *et al.,* 1982; Simmons *et al.,* 1986a; b; Meek *et al.,* 1998; Simmons, 2000; Redpath *et al.,* 2001; Amar *et al.,* 2003; Redpath *et al.* 2006), but may also indicate a male biased/skewed sex ratio (see Simmons, 2000). Support for the latter hypothesis comes from records of unpaired adult and immature males in suitable habitat (see Table 12). Furthermore, recent regional estimates of sex ratios that indicate a prevalence of males in areas exhibiting some of the largest population declines e.g. Slieve Aughties (O'Donoghue, 2010). Reduced levels of polygyny in other species is also associated with poor quality habitats (Leisler *et al.,* 2002), whereas polygyny rates are sometimes greater in "patchy" environments, where there is more variation in territory quality (Verner & Wilson, 1966).

Similar demographic effects were considered indicative of the decline in the Orkney hen harrier population (Amar & Redpath, 2002; Amar *et al.,* 2003; Amar & Redpath, 2005). The lack of polygyny found in the present study may be a consequence of the reduced assemblage of mammalian prey species within Ireland (Hayden & Harrington, 2000), sub-optimal foraging habitats with low diversity of avian prey (Smith *et al.,* 2001; Vanhinsbergh & Chamberlain, 2001; Thirgood *et al.,* 2003) or fragmentation of high quality foraging habitat necessitating larger foraging ranges (Garcia & Arroyo, 2005) to obtain sufficient food to provision mates and nestlings. Hen harriers often appear to hunt transiently through forest environments *en route* to open moorland/rough grassland (M. Ruddock, personal observation), often utilising tracks and fire breaks (see Watson, 1991). These observations are supported by data on the diet of harriers, which consists largely of moorland prey, such as meadow pipit and skylark (Scott, 2005; O'Donoghue, 2004; Ruddock *et al.,* 2008; O'Donoghue, 2010). Many nests, in Ireland appear to be several kilometres from the nearest moorland and as such, may considerably increase foraging ranges (Arroyo *et al.,* 2004 (in Scotland; males ~7.3km^2 and females ~3.6km^2); Garcia & Arroyo, 2005; Ruddock *et al.,* 2008; F. Leckie, personal communication). Many studies in Britain have shown that management of open habitats can have profound effects on hen harrier prey populations (Hope *et al.,* 1996; Chamberlain *et al.,* 1999; Vanhinsbergh & Chamberlain, 2001; Smith *et al.,* 2001; Buchanan *et al.,* 2006; Evans *et al.,* 2006a; b; Pearce-Higgins & Grant, 2006; Amar *et al.,* 2011). Managing upland landscapes so that they incorporate a diverse mosaic of habitat types and structures is likely to increase both abundance of prey populations and their availability to harriers, which in turn will have positive effects on hen harrier distribution and productivity (Hamerstrom, 1979; Hamerstrom *et al.,* 1985; Redpath & Thirgood, 1999; Madders, 2003, Wilson *et al.,* 2005; Scottish Natural Heritage, 2003).

Hatching and breeding success can be influenced by foraging habitat quality (Amar *et al.,* 2007) but also by weather (Redpath *et al.,* 2002c, Whitfield *et al.,* 2008), predation (Green & Etheridge, 1999; Amar & Burthe, 2001; O'Donoghue, 2010), disturbance and/or persecution (Etheridge *et al.,* 1997, Bro & Migot 2006, Whitfield *et al.,* 2008). In this study 2% of the males at confirmed territories were sub-adult males (i.e. second calendar year). Further monitoring of the age demographics of breeding pairs is required since the prevalence of sub-adults in the breeding population may suggest high turnover in the adult population and is a sign of a static or decreasing population (Newton, 1979; Balbontin, *et al.,* 2003; Whitfield *et al.,* 2004a; b) and/or high adult mortality which may be indicative of persecution

(Whitfield *et al.*, 2004a). However, there is limited comparative or historical data on persecution (see Etheridge *et al.*, 1997; Whitfield *et al.*, 2008) or age structure of the population on which to base this assertion and there are difficulties in ageing unmarked raptors in the field (Tingay *et al.*, 2007) and particularly hen harrier females (Hardey *et al.*, 2006; 2009).

It is apparent from longer term studies in Ireland that breeding demographics including success rates vary annually and regionally (Irwin *et al.*, 2008; O'Donoghue, 2010; Wilson *et al.*, 2012) and it is difficult to interpret the results from a single season survey, and with a small sample size. However, many key parameters appear consistently lower than in other parts of the hen harrier range and may require remedial actions. Inter-annual variation makes the collection and/or collation of long-term monitoring of temporal trends in occupancy and breeding parameters highly desirable, particularly for SPA populations. Whilst similar numbers of hen harriers were found in both recent national surveys (2005 & 2010); there have been notable declines in some regional and SPA populations, since the previous national survey (Barton *et al.*, 2006) with concomitant decreases also recorded during winter surveys (B. O'Donoghue, unpublished data). The figures in some breeding areas remain within the range of historical annual occupancy and/or breeding success figures (C. McGeough & J. Monaghan, personal communication). Numbers of breeding harriers in some regions of Ireland have undoubtedly been under-estimated and require further dedicated search effort in some areas, but this is unlikely to be the case in the areas where severe declines are noted e.g. Slieve Aughties and in the south-west (Irwin *et al.*, 2008; O'Donoghue, 2010; G. Oliver, personal communication; B. O'Donoghue, personal communication; Wilson *et al.*, 2012). Understanding the causes of these regional declines is a high research and management priority.

The long-term demographic trends of hen harrier populations in the SPAs are not known. However, it is possible to construct crude population models for each SPA using reproductive data for 2010 (see Appendix O) and assumed age-specific annual survival estimates. In the Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPA, for example, applying the annual adult survival rate of 0.778 (reported by Etheridge et al., 1997) to the population of 18 confirmed and 11 possible pairs representing 58 potential breeding birds present in 2010 indicates that twelve birds would die by the following year. These losses would be offset by the number of young produced in 2010 that survive to 2011, i.e. 11 x 0.361 (1st year survival rate reported by Etheridge et al.,) = 3.97 young, plus the net number of immigrants which is unquantified. In other words, if the Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle was a closed population, and assuming the above survival rates are applicable to Ireland, there would have been a net loss of nearly nine harriers in the number of potential breeding birds between 2010 and 2011 (Appendix O). Similarly, deficits of between 1.3 and 7.3 hen harriers are expected between 2010 and 2011 for four of the other SPAs; with the Slieve Blooms being the only area to have produced an expected surplus during 2010. Even allowing for substantial error in the assumed survival rates, and that they are derived from the persecuted Scottish population this analysis suggests that the SPA populations, except in the Slieve Blooms, are unable to support themselves without immigrants from other areas at least in the present year of study. A deficit of approximately 20 birds was estimated for breeding hen harriers outside the SPAs, bringing the estimated deficit of fledged young to 39 harriers for the Republic of Ireland (Appendix O).

The accuracy of the estimates generated by these models is expected to be low given the crude nature of the analysis and assumptions involved. For example, the adult survival estimate is likely to be conservative since it is based on female survival and male survival rate is almost certainly lower (Etheridge *et al.,* 1997). Pilot satellite tracking of juvenile hen harriers indicates dispersing birds are wide-ranging (see Reid *et al.,* in prep; IRSG & Golden Eagle Trust, unpublished data). However, all deployed transmitters failed to provide data into the second year suggesting that juvenile survival may be low. Low juvenile survival is also suggested by the small proportion of known wing-tagged individuals (out of more than 170) that are known to have entered the breeding population (Etheridge & Summers, 2006; O'Donoghue, 2010; B. O'Donoghue & M. Wilson, personal communication). Nevertheless this analysis indicates a possible dependency of the SPA populations on harriers breeding in the wider countryside and 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). With nett regional losses also reported from Northern Ireland (see Ruddock *et al.,* 2008; NIRSG, unpublished data) the availability of potential recruits from within Ireland may be sufficiently constrained to precipitate further declines in the hen harrier population in the near future. The available evidence suggests that the status of hen harrier populations in Ireland's SPAs is currently unfavourable and that remedial measures are urgently required. It would also imply, that even small increases in mortality rate (e.g. due to collisions with wind turbines or persecution by humans) is likely to adversely affect the viability of SPA harrier populations. The protection of other important areas for hen harriers as SPAs may also need considered e.g. Ballyhouras or Nagles.

5.0 Conclusions & Recommendations

The 2010 National Hen Harrier Survey shows evidence of severe declines in some areas, particularly in the west, south-west and SPAs whereas in other areas there is evidence of genuine increases. Comparatively the overall perspective is one of decline since 2005 within Ireland. It is recommended to continue pentadal national surveys of the hen harrier population; and the subsequent national survey (2015), will be important in assessing whether further declines occur. Similar previous surveys (Barton *et al.*, 2006), additional field effort identified new hen harrier nests, some in areas with high densities of breeding hen harriers. It therefore appears likely that breeding other hen harriers remain to be found throughout Ireland. Areas where increases in the field effort of future surveys are likely to yield new nest locations include Pettigoe, Blue Stacks, Donegal, Wicklow, and the Ox Mountains. However maintaining the high levels of existing coverage in other areas should also be afforded high priority.

Monitoring effort in the 2010 survey was unprecedented, but was highest in areas with known hen harrier occupancy and/or better habitats, and towards the end of breeding season. This complicates interpretation, comparability of surveys and the analysis of trends. Therefore, in future, the survey would benefit from improved statistical design and implementation by incorporating a fully randomised methodology (see Kovacs *et al.*, 2008; Saurola, 2008; Wernham *et al.*, 2008; Ewing *et al.*, 2011) perhaps initially in tandem with the existing survey method of the breeding range and commensurate with volunteer and/or field staff available. This would allow the estimation of confidence intervals and increase the accuracy of population estimates. This may require additional funds for the deployment of a greater number of seasonal fieldworkers during the next survey; as there were several fieldworkers funded outwith the core survey budget available during 2010 and these skills and knowledge base should be retained where possible for future surveys. Further integration of online reporting and submission of records is required to standardise formats of data (e.g. site names) and to expedite the collation of records for analysis.

In light of the difficulties in detecting trends between survey years it is recommended to establish annual monitoring squares and/or study areas to enable improved analysis of trends (Thompson *et al.*, 2003; Saurola, 2008; Hardey *et al.*, 2009; O'Toole *et al.*, 2009). Additionally, it is considered feasible to undertake annual monitoring for SPAs which should be prioritised and reported annually; perhaps with more structured deployment of volunteer effort and/or regional field staff dedicated to specific areas annually. The impression gained during the workshops and communication with fieldworkers; is that many datasets, some of them spanning several years, are collected and held by various individuals, agencies and organisations. However, these exist in a variety of locations and/or formats and so are not amenable to a pooled analysis. We highly recommend that such data (especially those data that are generated subsequent to this survey) are standardised and collated into a single database. As well as including details of locations, numbers and success of breeding hen harriers, such a database could also include other types of spatial information, such as data on persecution (including proven and/or anecdotal records), hen harrier movements, winter roost monitoring, habitat change, prey populations etc. It is likely that the aggregation of these data and on-going collation would facilitate more robust strategic analyses of Irish hen harrier population dynamics and predictive habitat modelling (see Fielding *et al.*, 2009; 2011). The database(s) should include a

mechanism for sharing of data, at an appropriate spatial scale, with land managers (such as foresters and farmers) and/or developers to facilitate protection of nest sites during forestry operations, wind energy development and ensure appropriate management decisions are taken.

Dramatic declines in numbers of breeding hen harriers were recorded in some areas, including SPAs, may require urgent remedial action to prevent further degeneration of regional populations. Understanding the reasons for such declines and investigating the role of habitat changes and other specific regional threats and trends as well as at national levels, will assist in determining what actions are likely to be most effective. We urge caution against the de-prioritisation of hen harrier conservation (Lynas *et al.,* 2008) and suggest that priority efforts to understanding the causes of declines and management requirements at a regional level be prioritised. Integration of practical forest management and design is required; and will no doubt be output following the completion of the UCC hen harrier research program in 2012 (Wilson *et al.,* 2010) but it is likely that further research and targeted management, particularly of foraging habitats, will be required in the long-term to optimise the value of these habitats with integrated management of burning and grazing regimes (Hobbs & Gimingham, 1987; Thompson *et al.,* 1995; Fuller *et al.,* 1999; Alonso *et al.,* Calvo *et al.,* 2002; 2001; Hartley & Mitchell, 2005; Amar *et al.,* 2005; 2009; Fotner *et al.,* 2007; Robinson, 2010; Amar *et al.,* 2011).

There is insufficient information on basic demographic parameters, in particular age-specific dispersal and survival rates in Ireland. These are necessary to develop and parameterise population models (see New *et al.,* 2011), which can improve our understanding of the effects of factors influencing mortality (e.g. due to windfarms) and reduced breeding success. In the long-term it is desirable to integrate information about survival, turnover and dispersal (see Etheridge *et al.,* 1997; Etheridge & Summers, 2006; Whitfield *et al.,* 2008) into a population viability model to further inform hen harrier conservation, policies and actions. In order to do this more information is required on survival, dispersal and turnover in Ireland. This can be derived from a number of different types of study including satellite telemetry, maintenance or expansion of the current programme wing-tagging, winter roost monitoring and/or population genetics (e.g. feather samples or buccal swabbing) taken from adults and/or juveniles (see Tingay *et al.,* 2007; 2009; Kenward *et al.,* 2007; Heap *et al.,* in press). The resources built-up in recent years in hen harrier research should, where possible, be maintained and new research initiated to carry out spatial analyses of habitat suitability (Fielding *et al.,* 2009; 2011) and to assess the observed effects of windfarms. Predictive and theoretical tools that may prove useful include spatial and/or constraint mapping (Osborn *et al.,* 1996b; McGrady *et al.,* 2002; McLeod *et al.,* 2003a;b; Walker *et al.,* 2005; Fielding *et al.,* 2006; Bright *et al.,* 2008; Tapia, 2009; Telleria, 2009a; b; c), modelling to improve understanding of cumulative effects of development at regional or national levels (Kerlinger, 2003; Smales, 2005; Masden *et al.,* 2009; Pearce-Higgins *et al.,* 2009), collision risk modelling (Tucker 1996a; b; Podolsky, 2003; 2005; Band *et al.,* 2005; Chamberlain *et al.,* 2005; 2006; Madders & Whitfield, 2006) and population modelling (using theoretical or empirically derived measures of mortality; Dillingham & Fletcher, 2008; Rasran *et al.,* 2009; Bekessy *et al.,* 2009; Carrete *et al.,* 2009). These are all important tools that can be used to improve decision making related to upland developments and hen harrier conservation and help decision makers to avoid undue conflict with national and public interests while complying with statutory responsibilities.

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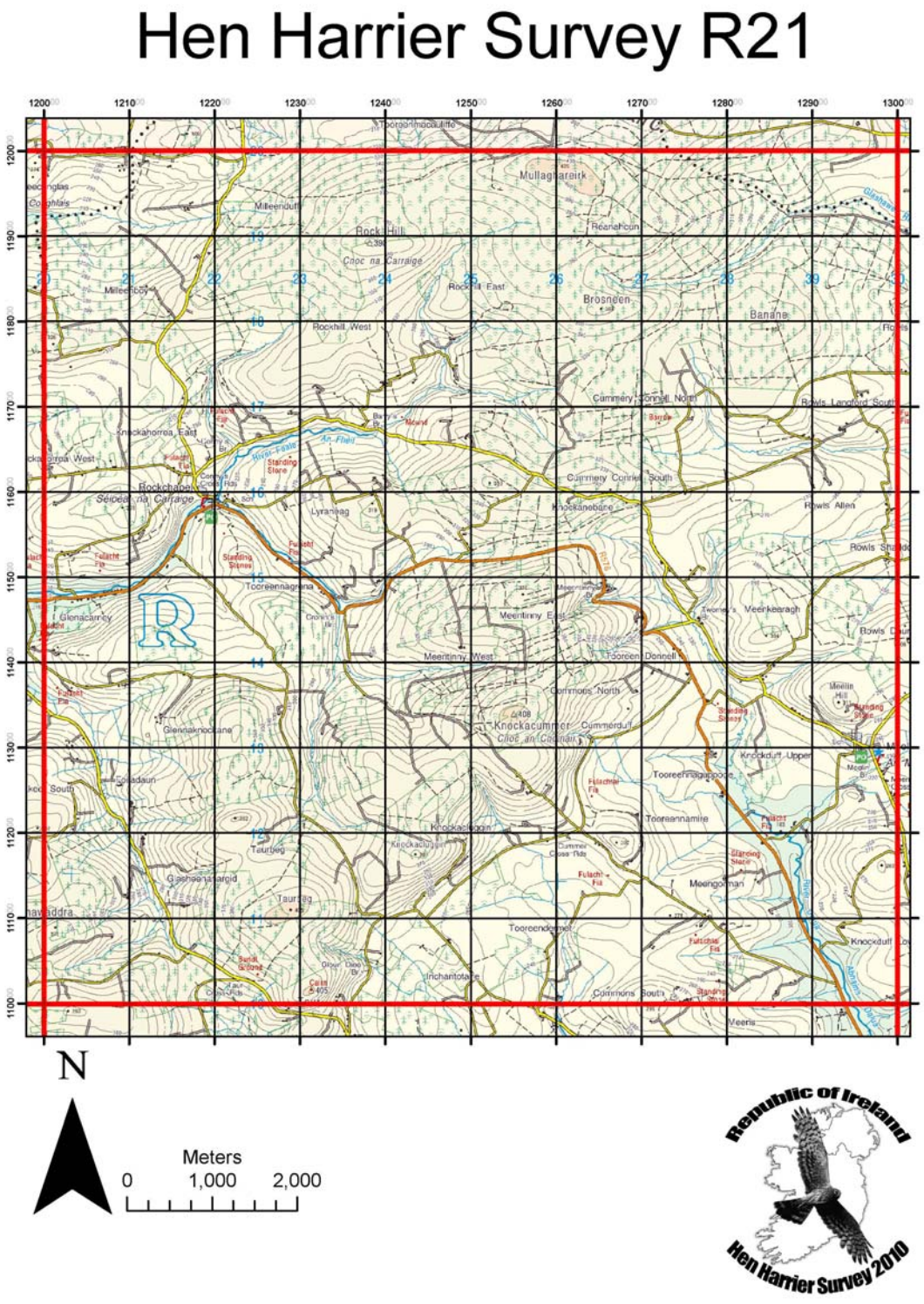
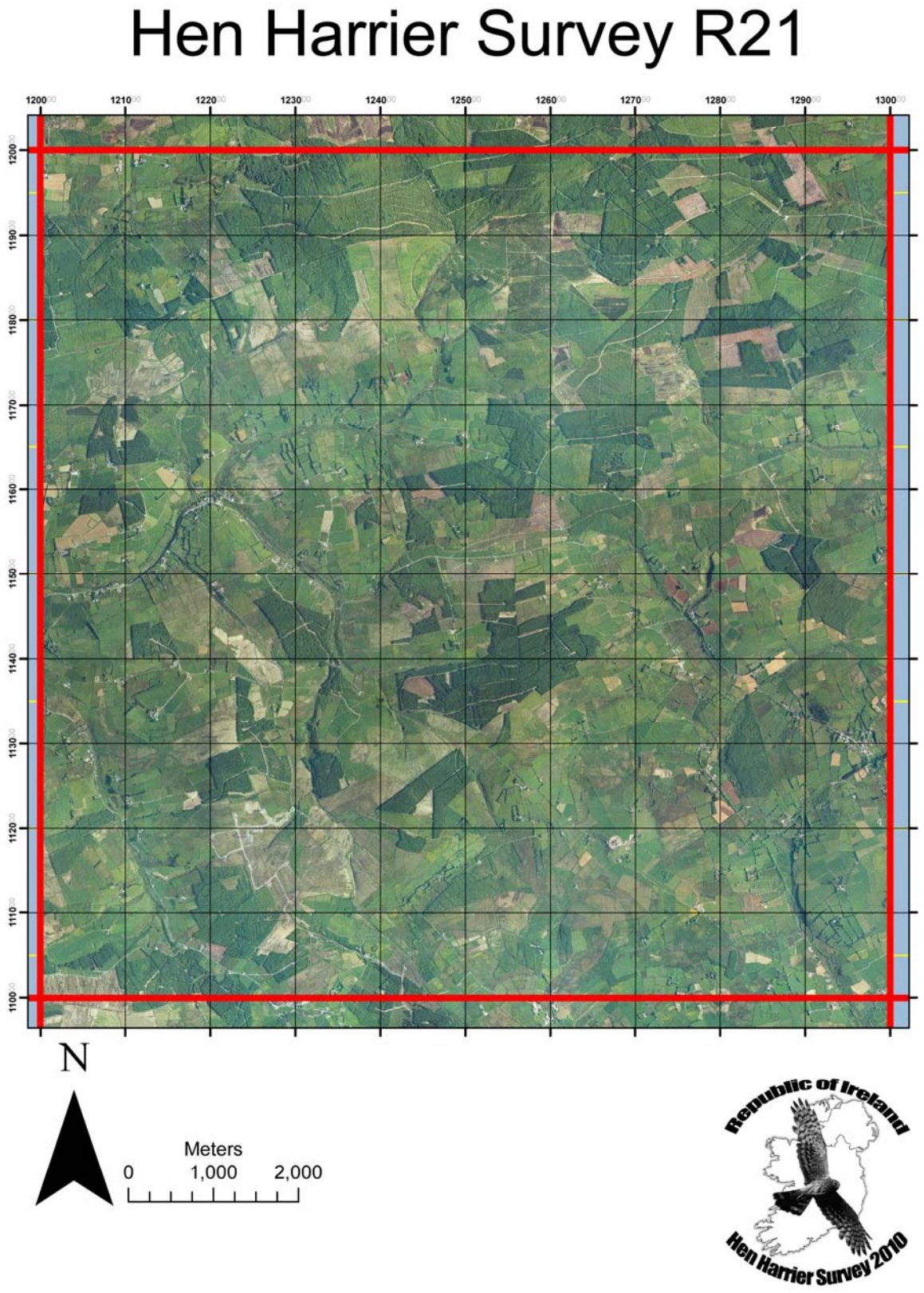
7.0 Appendices

Appendix A. 10km square 1:50000 OSI map showing topography, geo-referenced grid and habitats.



Appendix B. 10km square aerial photograph showing distribution of habitat types and geo-referenced grid lines.



Appendix C. Moulted feather collection sheet and instructions

HEN HARRIER MOULTED FEATHER COLLECTION DATA SHEET

Please return this sheet with your samples to: Dr Marc Ruddock, Cemetery Cottage, 12 Church Street, Greyabbey, Co. Down, BT222NQ *or* Dr Allan Mee, Direen, Black Valley, Beaufort, Co. Kerry, Ireland

Name: _____ Email: _____

Telephone: _____ Address: _____

Grid Reference (min 6 figure, pref 10 figure)	*Site Name*	*Nest, Roost or other?*	*Site occupied or unoccupied by resident pair?*	*Collection date (dd/mm/yy)*	*# Feathers collected*	*Comments*

MOULTED FEATHER COLLECTION PROTOCOL

1. Collect moulted feathers from nest (only with a licence) and/or roost site. DNA is found in the calamus (lower tip of the feather shaft) and in the small blood spot just below the plume so feathers with the lower half missing cannot be used to extract DNA. Body, contour, wing and tail feathers are all suitable for collection (because they have a substantial shaft). Feathers with a split or broken feather shaft tip are unsuitable (due to potential contamination). Down feathers from adults / sub-adults are unsuitable for collection.
2. All feathers (suitable and unsuitable) should be removed from the site to avoid repeat collection at a later date. Unsuitable feathers should be disposed of away from the site.
3. Carefully wipe off any mud, water etc from the suitable feather(s).
4. Large feathers (e.g. tail / wing) may be cut for easier storage, provided the lower half of the feather (calamus and blood spot) remains intact.
5. Store the suitable adult / sub-adult feathers in a dry paper envelope **at the collection site**. Plastic bags should not be used for storage as moisture can cause decay to the shaft and subsequently the DNA.
6. **Feathers from different nest/roost sites must be stored in separate envelopes**.
7. **Feathers collected from same site but on different dates must also be stored separately**.
8. Record the following information (please write clearly) on note paper using pencil or water-resistant pen and place inside the envelope:
    - Full grid reference of collection location (minimum 6 figure, preferably 10 figure)
    - Collection location site name (be consistent between visits/years)
    - Nest / roost site (or other, e.g. hillside)
    - Site occupied or unoccupied by resident pair (if not sure, write 'unknown')
    - Collection date (including dd / mm / yy)
    - The number of feathers collected
    - The collector's name
9. Record the same information on the outside of the envelope using a water-resistant pen.
10. Record the same information on the data sheet (see reverse of this sheet).
11. Store the envelopes dry at room temperature. Please do not put the envelopes in a fridge or freezer.
12. Send envelopes with completed data sheets to the address on the reverse side of this sheet.

Appendix D. Prey remains collection sheet and instructions

HEN HARRIER PELLET AND/OR PREY REMAINS COLLECTION DATA SHEET

Please return this sheet with your samples to: Dr Marc Ruddock, Cemetery Cottage, 12 Church Street, Greyabbey, Co. Down, BT222NQ *or* Dr Allan Mee, Direen, Black Valley, Beaufort, Co. Kerry, Ireland

Name: _____ Email: _____

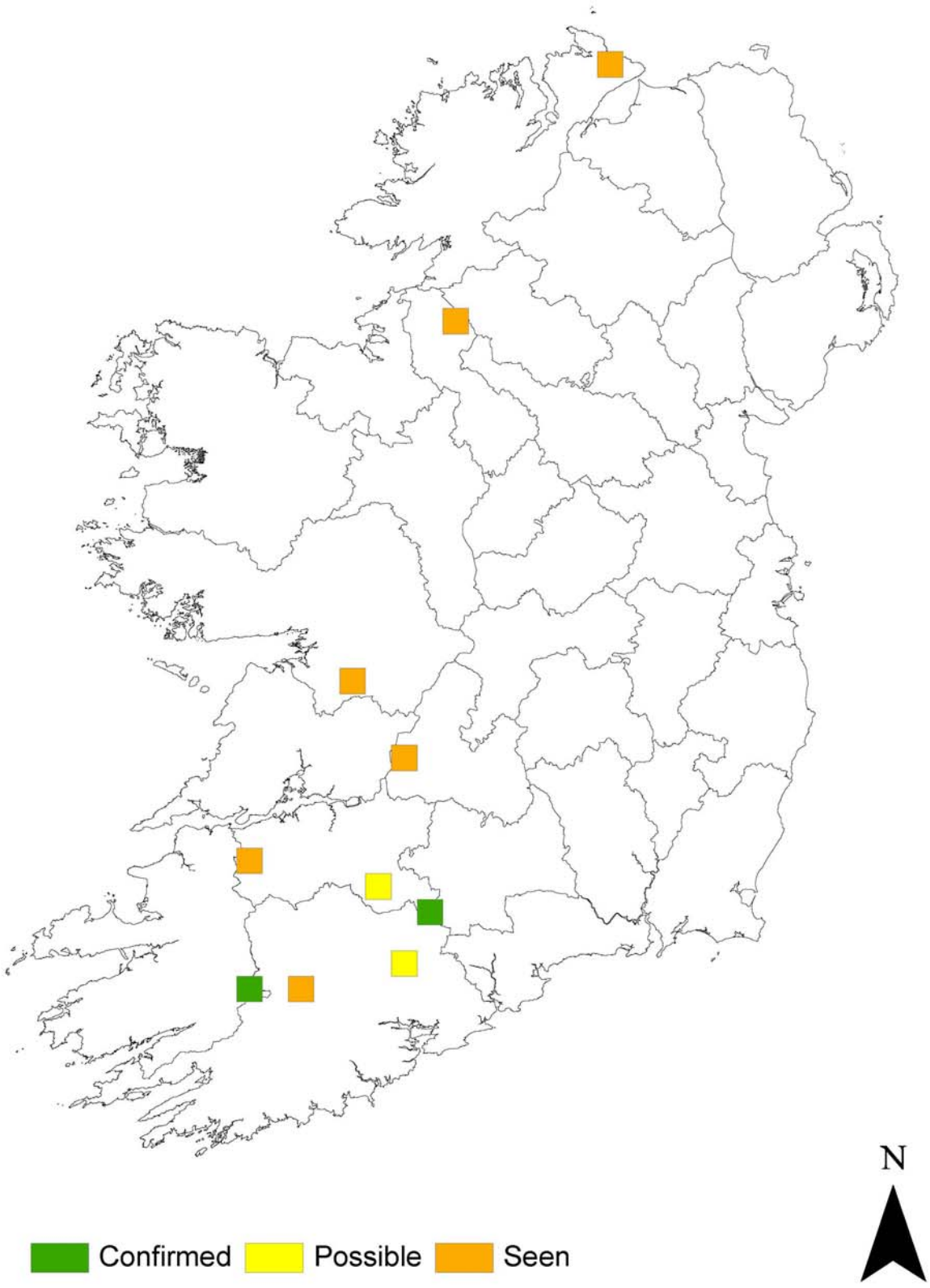
Telephone: _____ Address: _____

Grid Reference (min 6 figure, pref 10 figure)	*Site Name*	*Nest, Roost or other?*	*Site occupied or unoccupied by resident pair?*	*Collection date (dd/mm/yy)*	*# pellets collected*	*# prey remains collected*	*Comments*

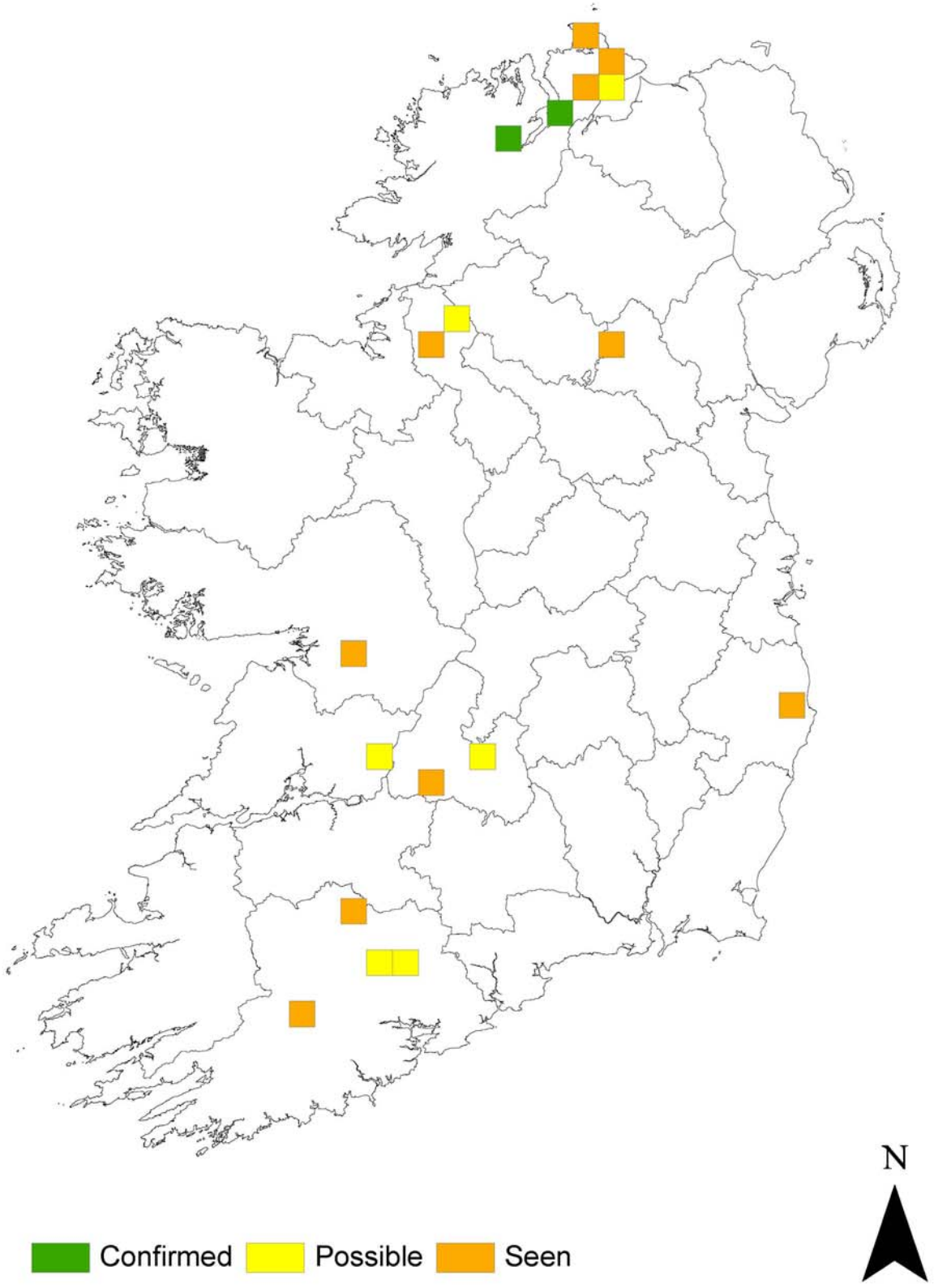
PELLETS & PREY REMAINS COLLECTION PROTOCOL

1. Collect pellets and/or prey remains from nest (only with a licence), roost site or other locations.
2. All pellets and/or prey remains should be stored in envelopes or plastic sample bags.
3. Store the pellets and/or prey remains in a dry paper envelope or plastic bags **at the collection site**. Plastic bags should only be used for storage if you are able to freeze or dry the samples within 24 hours as moisture can cause rapid decay of samples.
4. **Pellets and/or prey remains from different nest/roost sites must be stored in separate envelopes/bags**.
5. **Pellets and/or prey remains collected from same site but on different dates must also be stored separately**.
6. Record the following information (please write clearly) on note paper using pencil or water-resistant pen and place inside the envelope/bag:
    - Full grid reference of collection location (minimum 6 figure, preferably 10 figure)
    - Collection location site name taken from the 1:50000 map (be consistent between visits/years)
    - Nest / roost site (or other, e.g. hillside, fence post etc)
    - Site occupied or unoccupied by resident pair (if not sure, write 'unknown')
    - Collection date (including dd / mm / yy)
    - The number of pellets collected
    - The number of prey remains collected
    - The collector's name
7. Record the same information on the outside of the envelope/bag using a water-resistant pen.
8. Record the same information on the data sheet (see reverse of this sheet).
9. Pellets & prey remains should be dried or frozen to prevent decomposition prior to posting.
10. Send envelopes/bags with completed data sheets to the address on the reverse side of this sheet.

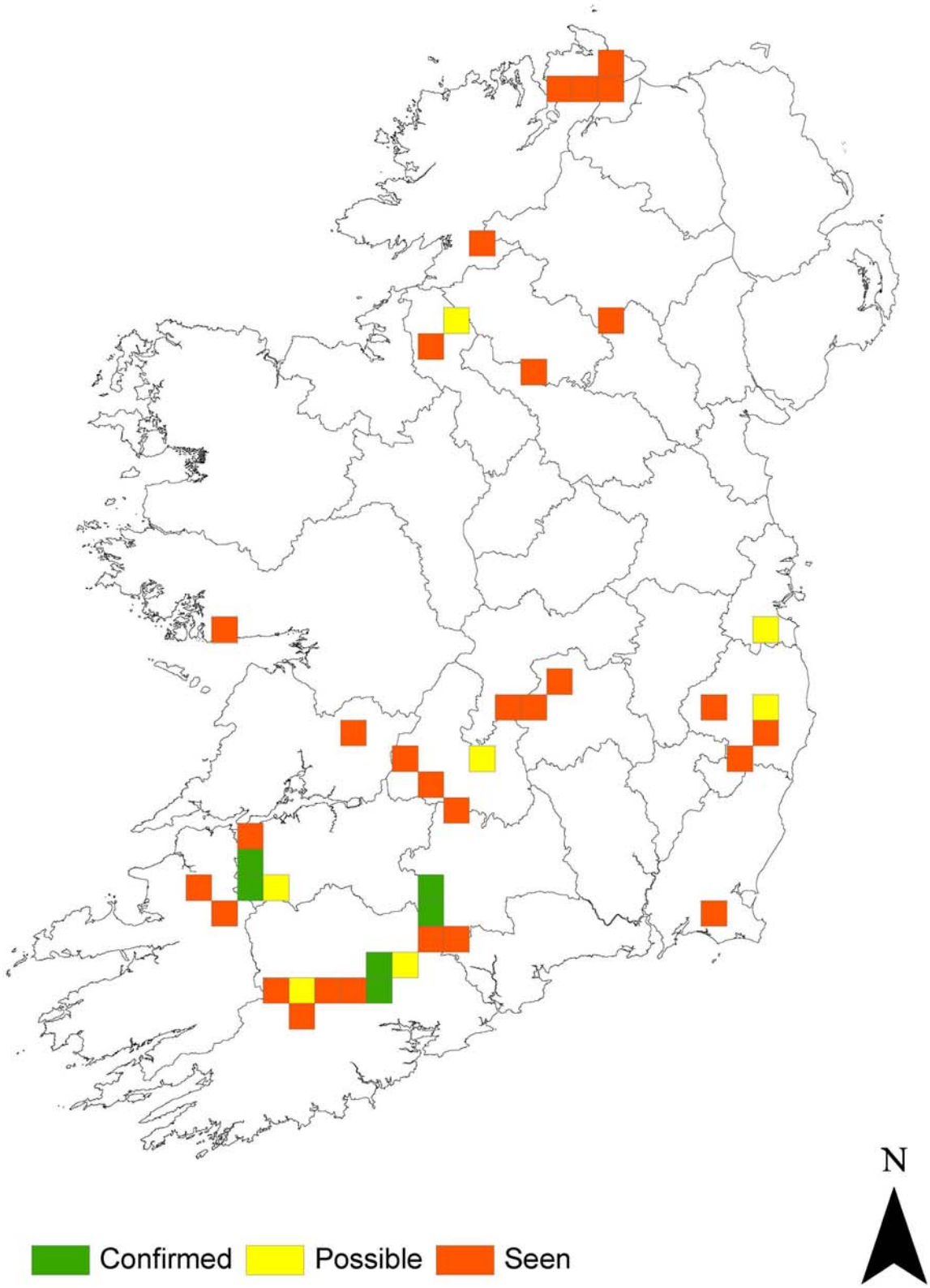
Appendix E. Map showing distribution of 10km squares containing merlin records.



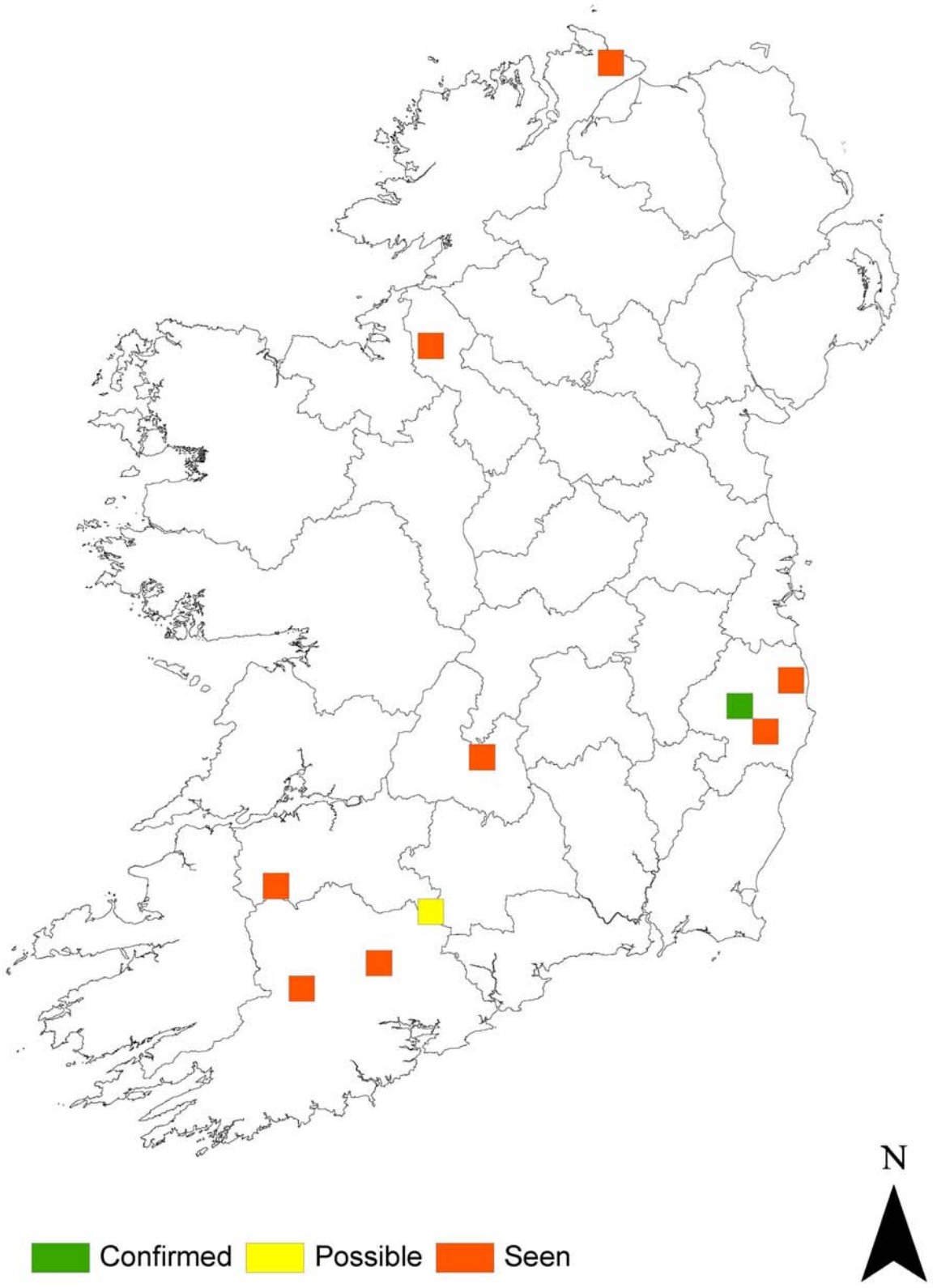
Appendix F. Map showing distribution of 10km squares containing buzzard records



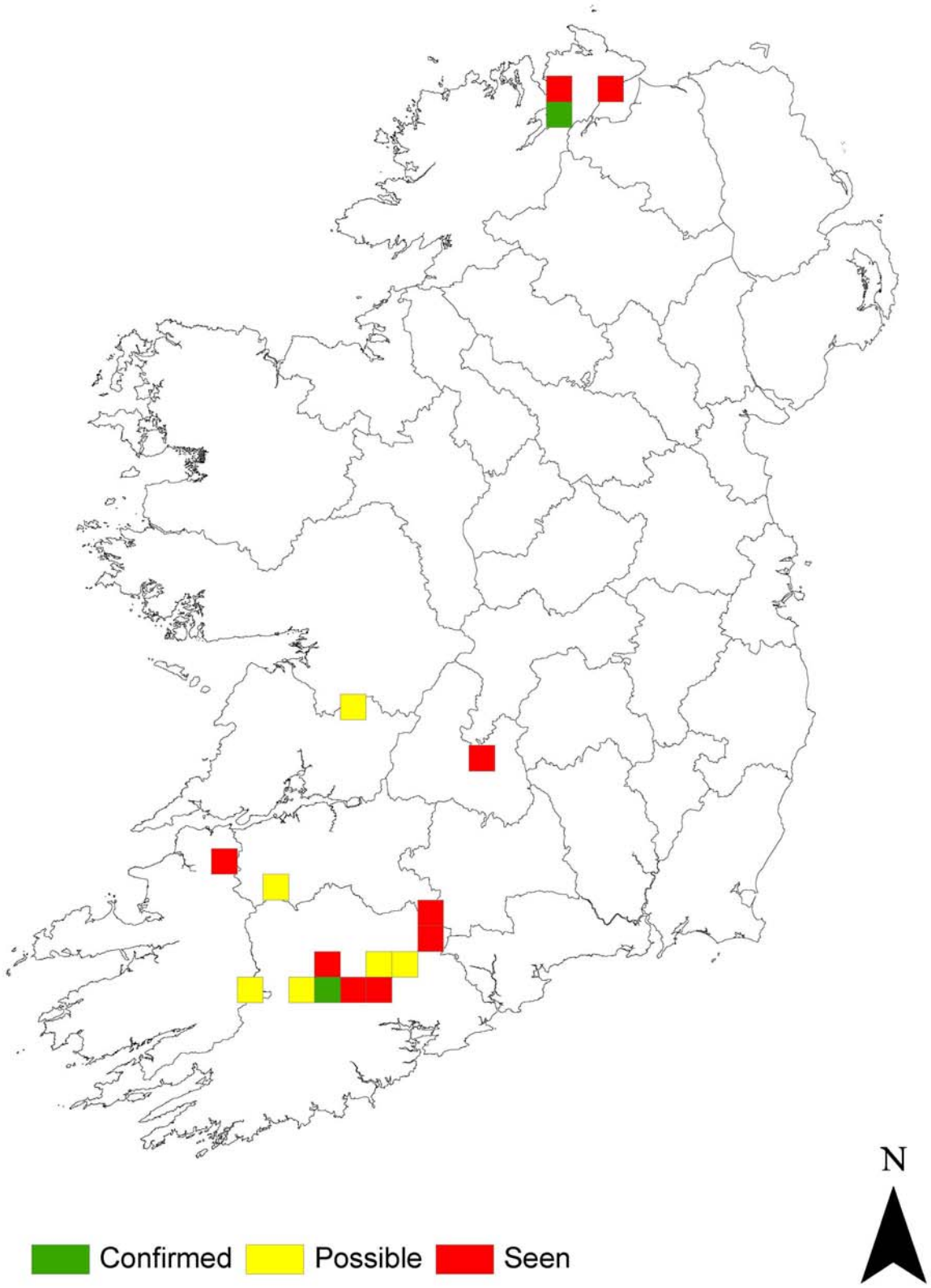
Appendix G. Map showing distribution of 10km squares containing kestrel records



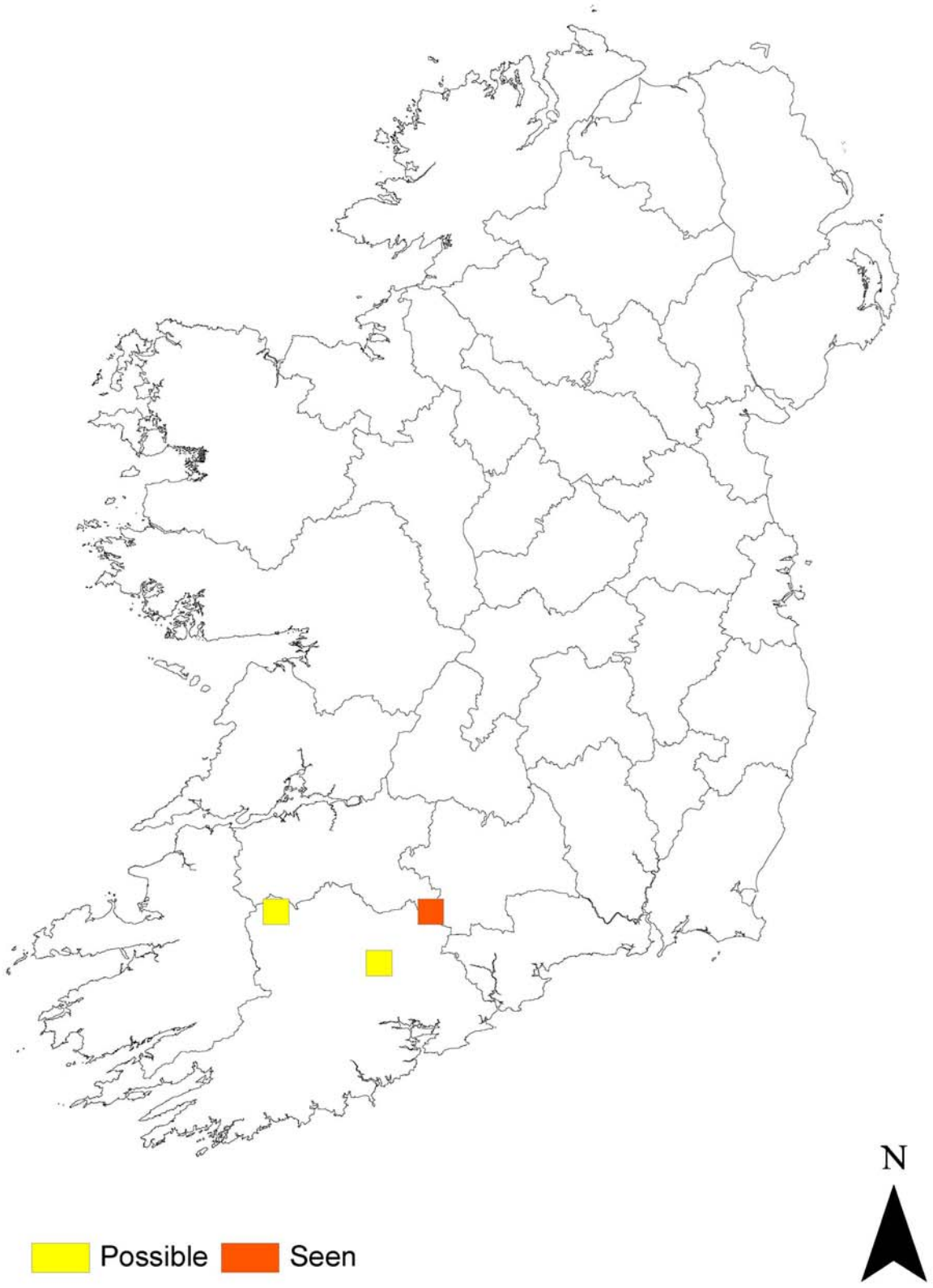
Appendix H. Map showing distribution of 10km squares containing peregrine records.



Appendix I. Map showing distribution of 10km squares containing sparrowhawk records

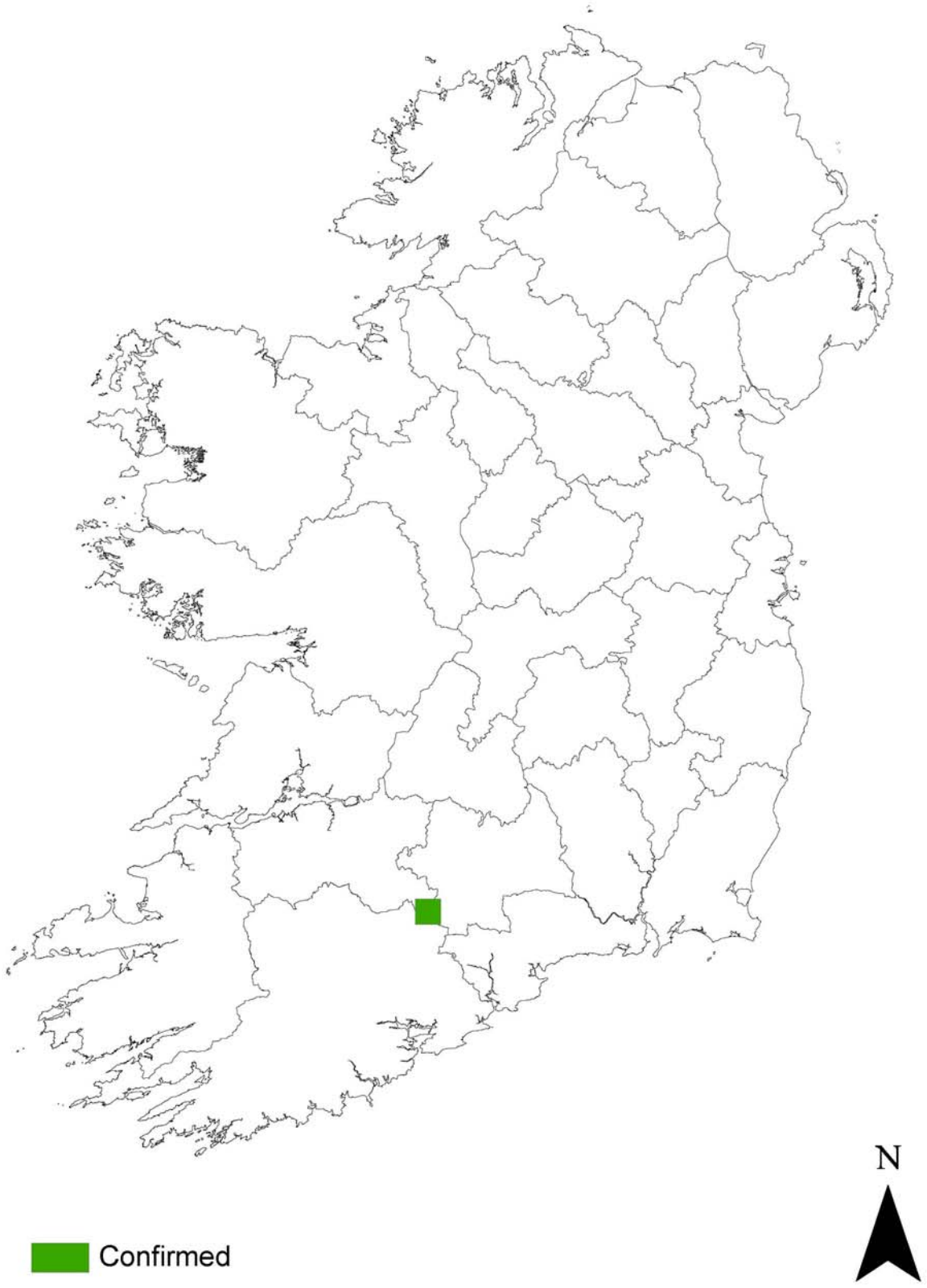


Appendix J. Map showing distribution of 10km squares containing goshawk records

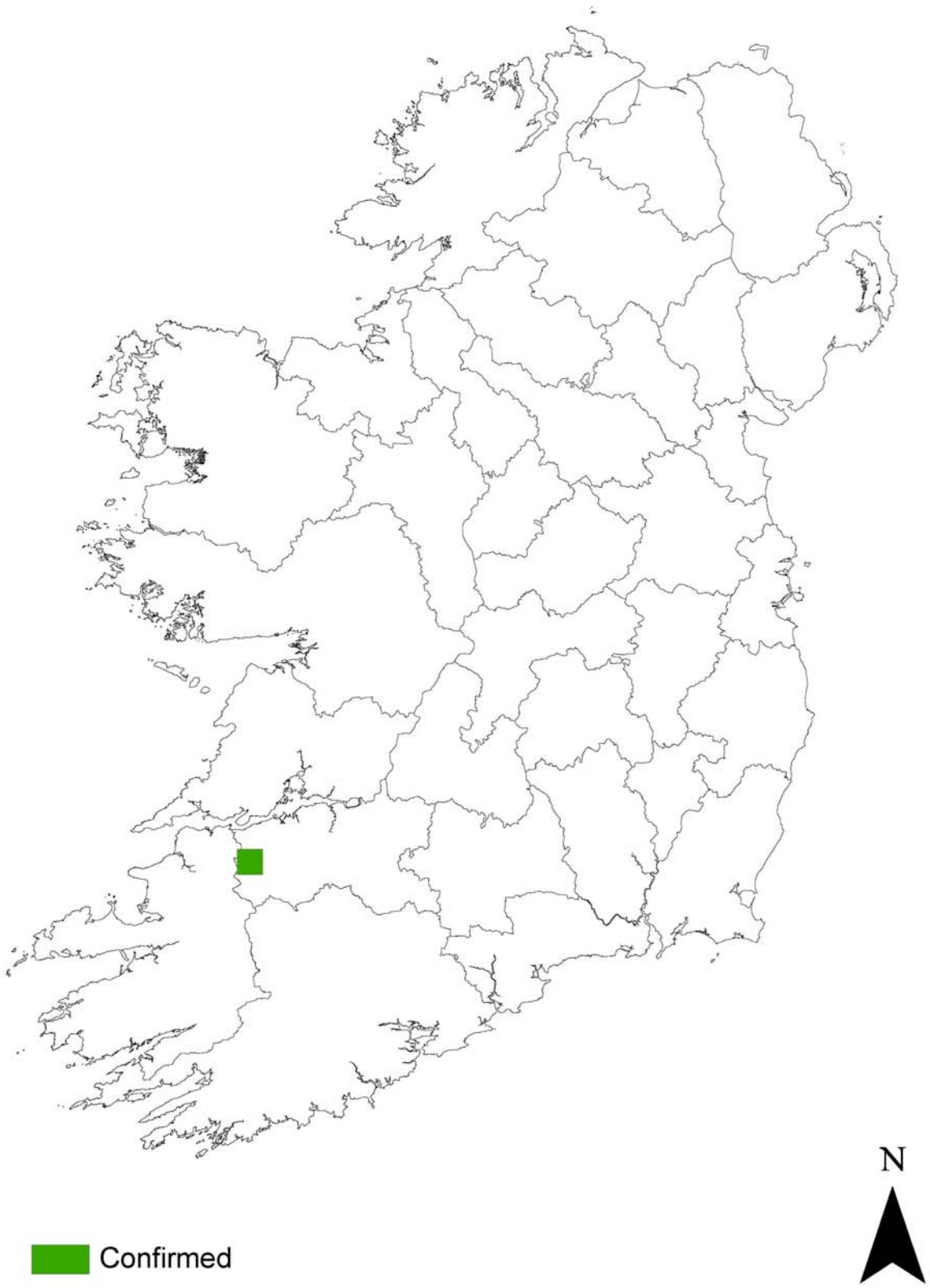


Appendix K. Map showing distribution of 10km squares containing red kite records

Appendix L. Map showing distribution of 10km squares containing long-eared owl records



Appendix M. Map showing distribution of 10km squares containing barn owl records



Appendix N. Photographs showing juvenile (still in sheath) hen harrier feathers with chewed ends, probably as a result of fox predation.

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

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
Stack's to Mullaghareirk Mountain, West Limerick Hills & Mount Eagle	2010	18	11	58	0.778	45.124	12.876	0.38	11	0.361	3.971	-8.91
Mullaghanish to Musheramore Mountains	2010	2	1	6	0.778	4.668	1.332	0	0	0.361	0.000	-1.33
Slievefelim to Silvermines Mountains	2010	6	1	14	0.778	10.892	3.108	0.57	4	0.361	1.444	-1.66
Slieve Bloom Mountains	2010	9	0	18	0.778	14.004	3.996	1.89	17	0.361	6.137	2.14
Slieve Aughty Mountains	2010	15	8	46	0.778	35.788	10.212	0.35	8	0.361	2.888	-7.32
Slieve Beagh	2010	8	1	18	0.778	14.004	3.996	0.33	2	0.361	0.722	-3.27
Outside SPAs	2010	73	22	190	0.778	147.82	42.18	0.85	62	0.361	22.382	-19.80
Whole population	2010	128	44	344	0.778	267.632	76.368	0.6	104	0.361	37.544	-38.82