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The 2022 National Survey of breeding Hen Harrier in Ireland

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Front cover, small photographs from top row:

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

Bottom photograph: **Hen harrier** female in flight, Marc Ruddock

The 2022 National Survey of breeding Hen Harrier in Ireland

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Executive Summary

Capsule: The hen harrier is a rare bird of prey with a declining population in Ireland. The fifth national survey of the species in Ireland has documented further population declines and a diminished range, both in the wider countryside and within Special Protection Areas (SPAs).

Aim: To examine the abundance and distribution of hen harrier in Ireland, to estimate the change in the population size and distribution across their breeding range nationally and within the six Special Protection Areas (SPAs) designated for breeding hen harrier.

Methods: In 2022, field surveys were undertaken during the breeding season within 10 km squares across the known and/or likely range of breeding hen harrier, using standardised methods employed during previous national surveys (1998-2000; 2005; 2010 and 2015). The latest survey allows an assessment of changes to the population over time. The 2022 national survey achieved high levels of coverage, an estimated 93% of the breeding range, with a minimum of 7,700 survey hours completed by circa 250 surveyors.

Results: The hen harrier population in Ireland was estimated at 84 confirmed and 21 possible breeding pairs (85-106) in 2022. This is a decline of one third (33%) in the total population since the previous national survey in 2015 and a 27% contraction in their breeding range for the same period. A review of data for those squares covered in all surveys (long-term change), and squares covered consistently between consecutive surveys (*i.e.* a subset analyses), indicates that declines in both range and population have occurred in the short-term (2015); medium term (2010/2005) and long-term (1998-2000).

Estimated rates of breeding success and productivity remain low (0.7 fledged young per breeding pair) and are below the minimum recruitment rate (1.0 fledged young per breeding pair) typically required to maintain a stable population. The populations of five of the SPAs have declined by between 20% and 80% since 2007, when they were identified for designation. In the same period, the population for only one SPA has increased (12%). Overall, the SPA populations have declined by more than half (54 %) in the same period.

Conclusion: The hen harrier breeding distribution in Ireland has contracted further since the 2015 survey, and the total national population has also declined. The extent of declines varies locally, regionally and between SPA populations. These ongoing declines warrant continued conservation efforts, surveys (including targeted monitoring), the urgent implementation of the long-awaited national Hen Harrier Threat Response Plan (HHTRP), as well as appropriate resources and funding for the delivery of these actions.

Given the continued declines, and myriad of pressures and threats acting on hen harrier in Ireland, it is also likely the hen harrier will feature on the next Red-list of the Birds of Conservation Concern in Ireland (BoCCI) subject to a full assessment using the BoCCI Red-list criteria. This recommendation will also likely be informed by the specific subset analyses carried out which compared the 2022 results for squares also covered in each of preceding national surveys. These subset analyses have demonstrated a >50% decline since both the first national survey 1998-2000 and the second national survey in 2005.

It is imperative that conservation measures to increase the distribution and abundance of the species are urgently reviewed and all necessary actions to support recovery of the hen harrier in Ireland are implemented.

Acknowledgements

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1. Introduction

Raptors are indicators of ecosystem health (Donázar *et al.*, 2016) and provide important ecosystem services as scavengers and predators (O'Bryan *et al.,* 2018). Over half of the world's raptors are declining (McClure *et al.,* 2018). These declines are linked to the wider global biodiversity crisis (Elbert, 2002; Singh, 2002; Hoag, 2010; Marques *et al.,* 2019; Nature, 2021). This crisis has seen substantial losses in both distribution (and range) and populations of species including raptors (Cruz *et al.,* 2021) and is often interconnected with conservation policy (Bateman & Balmford, 2023). For raptor populations, such declines can have a destabilising effect in trophic chains and biological communities (Lees *et al.*, 2013; Terraube & Bretagnolle, 2018).

Raptor monitoring and surveying are key processes for tracking and measuring the performance of populations over time (Hardey *et al.,* 2013). The data collected can be used to inform conservation status and inform management and actions (McClure *et al.,* 2018). It is important that monitoring provides clear and concise information on what is happening and what changes are occurring and that methods are standardised to ensure the reduction of errors of estimation, improve estimation, and increase robustness of outputs (McClure *et al.*, 2022). Monitoring enables a review of risk and evaluation of the population, assessment of possible actions, and innovation towards shared solutions. Monitoring provides strategic oversight, trend analysis, and target or goal setting. Results derived from monitoring enhance understanding of external factors, context, and national or regional differences. The publication of monitoring information can help improve stakeholder relationships, advocacy, and strategic planning and facilitates feedback loops, population restoration and conservation management.

The hen harrier *Circus cyaneus* is a medium-sized raptor, typically found in upland areas in Ireland and the United Kingdom of Great Britain and Northern Ireland (UK) (Hardey *et al.*, 2013; Ruddock *et al.,* 2016; Wotton *et al.*, 2018). The hen harrier is red-listed in the UK due to historical and continued declines (Stanbury *et al.,* 2021) and is amber-listed in Ireland due to moderate long-term breeding population declines (Gilbert *et al.,* 2021).

The most recent European Red List (BirdLife International, 2021) categorised hen harrier as 'vulnerable' for the 28 European Union Member States (or EU28), including Ireland, and was informed by the best available population and distribution (or range) data. Declines across several European countries in both population size and distribution (or range) have been described previously (Keller *et al.*, 2020; Fernandez-Bellon *et al.,* 2021). Across Europe, the hen harrier is subject to a range of ongoing pressures and threats. The main drivers of its decline are the ongoing loss and degradation of suitable nesting, foraging, and wintering habitats (Amar & Redpath, 2005; Amar *et al. 2003; 2004; 2005; 2007; 2008; 2011*, Arroyo *et al.,* 2009; Redpath *et al.,* 2010; O'Donoghue *et al.*, 2011; Ruddock *et al.,* 2016; Thompson *et al.,* 2016; Wotton *et al.*, 2018; Caravaggi *et al.,* 2020; Fernandez-Bellon 2020; Newton, 2020; Ewing *et al.*, 2023), as well as on-going targeted persecution across its range (O' Donoghue *et al.,* 2011; O' Donoghue, 2019; Murgatroyd *et al.,* 2019).

Historically in Ireland, there was a rapid retraction in the distribution (or range) of the hen harrier from most occupied areas of Ireland between 1875 and 1900, so much so that by the turn of the 20th Century, breeding was confirmed only in south-west Munster and the mountains of Connaught (Thompson, 1849; Ussher & Warren, 1900). Losses were attributed to the destruction of breeding habitat, with localised extinctions first noted on lowland breeding sites, thereby isolating the species in the uplands where they subsequent also declined. In the early 20th century, the upsurge in raptor persecution, as interests in game shooting and game preservation grew, resulted in a significantly diminished hen harrier population in Ireland and Britain (Watson, 1977).

Protective legislation, a reduction in game-keeping activities and planting of young forest plantations in the uplands resulted in the recolonisation of the hen harrier to previously vacated

areas in the second half of the 20th century (O'Flynn, 1983). Between 1950 and 1970, population recovery of hen harriers in Britain likely aided recovery in Ireland, although localised losses continued due to habitat loss and other changes, including agricultural intensification, afforestation, and persecution (O'Flynn, 1983). Hen harriers now breed in sub-optimal forest plantations (Wilson *et al.,* 2012) that have been planted in former breeding habitats, when the trees are in pre-thicket stage (<15 years of age; more typically <12 years of age). However, maturing (>15 years old) plantations are unsuitable, for nesting or hunting (NPWS, 2015a). Nowadays, the hen harrier breeds mainly in the uplands in Ireland, in localised, but fragmented areas of suitable heath and blanket bog and afforested habitats where, in many areas, steep population declines have been evident.

There have been a series of strategic monitoring efforts of the hen harrier in the UK and Ireland, namely the various breeding (and wintering) Bird Atlas surveys which have described the distribution and abundance of the hen harrier (Sharrock, 1976; Gibbons *et al.*, 1993; Balmer *et al.,* 2013) and a number of targeted single-species national surveys, lastly in Ireland in 2015 (Ruddock *et al.*, 2016) and in the UK in 2016 (Wotton *et al.,* 2018). As set out in these aforementioned surveys, the Great Britain population has always been larger than that of Ireland and Northern Ireland given the larger extents there of appropriate open moorland, bog, and heathland habitats (ONS, 2022; CSO, 2021). The interchange *i.e.* movement and dispersal connections, between these island populations has been proven (Etheridge & Summers, 2006).

The UK populations have ranged from 570 ± 150 pairs in 1988-89 (Bibby & Etheridge, 1993); again 570 pairs in 1998 (Sim *et al.,* 2001); and then increasing to 806 pairs in 2004 (Sim *et al.*, 2007); before declining in both subsequent surveys to 662 pairs in 2010 (576-770; Hayhow *et al.,* 2013) and then 575 pairs in 2016 (477-694; Wotton *et al.*, 2018). The first Atlas of Breeding Birds in Britain and Ireland (Sharrock, 1976) broadly estimated 200 – 300 pairs of hen harrier during 1968-1972. Subsequently, Watson (1977) based on expert option (D. Scott) estimated the population at 250 – 300 pairs in Ireland by 1973-75. The second Atlas of Breeding Birds in Britain and Ireland (Gibbons *et al.,* 1993) reported around 180 pairs (All-Ireland).

The hen harrier population in Ireland was first strategically surveyed, via a national survey during the period 1998 – 2000 (Norriss *et al.*, 2002), and in subsequent national surveys of 2005 (Barton *et al.,* 2006), 2010 (Ruddock *et al.*, 2012) and 2015 (Ruddock *et al.,* 2016). The first national survey recorded 102 – 129 pairs (Norriss *et al.,* 2002). Apparent national increases were recorded in the two subsequent surveys in 2005 (132 – 152 pairs; Barton *et al.,* 2006) and 2010 (128 – 172 pairs; Ruddock *et al.,* 2012) although survey effort was also increased during those surveys. During the 2015 survey, there were 108 – 157 pairs of hen harrier recorded which was a decline from previous surveys. Sub-set analyses, which were comprised of an assessment of hen harrier breeding pairs in survey squares which were surveyed across two or more national surveys, further confirmed like-for-like comparative results, corroborating those declines (Ruddock *et al.*, 2016). The hen harrier population in Ireland increased during the period of the first two national surveys but has steadily declined since the 2010 national survey.

The Northern Ireland surveys are part of the UK national survey sampling regimen; there have been five published national surveys of the hen harrier in the UK and Isle of Man. In Northern Ireland, there were 10 pairs recorded in 1989/90. However, the coverage of that survey was thought to be incomplete (Bibby & Etheridge, 1993). The follow-up survey in 1998 recorded 38 territorial pairs (Sim *et al.*, 2001); 63 territorial pairs were recorded in 2004 (Sim *et al.*, 2007), 59 territorial pairs were recorded in 2010 (Hayhow *et al.*, 2013) and the fifth survey (2016) recorded 46 pairs (Wotton *et al.,* 2018). A sixth national UK survey (including Northern Ireland) got underway in 2023, with results expected in 2024. In an All-Ireland context there were 130 – 167 pairs (All-Ireland) reported based on the 28 – 38 pairs reported in Northern Ireland by Sim *et al*., 2001) combined with a national population estimate in Ireland of 102 – 129 pairs (Norriss *et al.,* 2002). This estimate was lower than the Gibbons *et al.,* (1993) estimated population of 180 pairs (All-Ireland).

The conservation status of the species on an all-Ireland basis was downgraded from Red to Amber on the Birds of Conservation Concern in Ireland list in the early 2000s (Newton *et al.,* 1999; Lynas *et al.*, 2007) due to the numbers recorded at the time (including the 1998-2000 national survey; Norriss *et al.*, 2002). In the intervening Red-list updates since then, it has been assessed as Amber, including in the fourth assessment of Birds of Conservation Concern in Ireland (Gilbert *et al.,* 2021). The species has remained Red-listed in the UK throughout these same decades, including the most recent assessment (Stanbury *et al.,* 2021). Regular surveys of rare or scarce species are necessary to establish their status, including spatial distribution and abundance and changes therein, in order to inform conservation assessment and prioritisation of actions required.

Article 12 of the EU Birds Directive requires that Ireland prepares a report on the implementation of the Directive, now every six years. This is to include information on the status and trends of all bird species occurring here. In part fulfilment of this obligation, Ireland undertakes a national survey of the hen harrier, typically every five years, including at the six Special Protection Areas (SPAs) (see www.npws.ie/protected-sites); namely (i) the Slieve Bloom Mountains SPA (Site code: 4160); (ii) the Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPA (Site code: 4161); (iii) the Mullaghanish to Musheramore Mountains SPA (Site code: 4162); (iv) the Slievefelim to Silvermines Mountains SPA (Site code: 4165); (v) Slieve Beagh SPA (Site code: 4167); and (vi) the Slieve Aughty Mountains SPA (Site code: 4168). Overall, the total SPA population declined by 18.1% between the 2005 and 2010 national surveys (Ruddock *et al.,* 2012) and by 28% between the 2010 and 2015 national surveys (Ruddock *et al.,* 2016).

This survey (2022) is the fifth national survey. The Golden Eagle Trust, Irish Raptor Study Group and BirdWatch Ireland formed a partnership to co-ordinate the 2022 Irish Hen Harrier Survey on behalf of the National Parks & Wildlife Service of the Department of Housing, Local Government and Heritage (DHLGH). The national survey has five key objectives:

- Obtain a reliable estimate of the size of the hen harrier breeding population in Ireland in 2022;
- Obtain a reliable estimate of the distribution of the hen harrier breeding population in the Ireland in 2022;
- Estimate the change in population size and distribution since the last surveys in 1998 – 2000; 2005; 2010; and 2015;
- Compare the distribution and size of the hen harrier populations within the six Special Protection Areas (SPAs) since the surveys in 2005, 2010 and 2015;
- Review and document ancillary data collected during 2022, including any details on breeding habitats, breeding success and productivity and pressures and threats.

2. Methods

2.1 Objectives

To establish population estimates, the primary objective of the hen harrier survey is to identify whether suitable habitat is present and occupied by breeding hen harrier. Secondary objectives are to establish whether a breeding attempt was initiated and to establish breeding outcome (*i.e.* success or failure of a nest and, if successful, establish the number of fledged young).

2.2 Survey design and implementation

The primary areas identified for survey within the breeding range of the hen harrier were defined as those 10 km national grid squares within which hen harrier were observed during the four national surveys completed thus far and which will be referenced using the titles below for the remainder of this report:

- 1998-2000 survey (Norriss *et al*., 2002)
- 2005 survey (Barton *et al.,* 2006)
- 2010 survey (Ruddock *et al.,* 2012)
- 2015 survey (Ruddock *et al.,* 2016)

Collectively, the above surveys are referred to as 'previous national surveys'.

Potentially suitable breeding areas for hen harrier were identified as mountain ranges/upland areas previously defined by Norriss *et al.,* (2002; Table 9). Hen Harriers nest across a range of elevations (36-385 m a.s.l.), but largely are confined to upland locations (>100 m to <600 m a.s.l.); O'Donoghue, 2010; Ruddock *et al.,* 2016). These areas were divided into individual survey units using the 10 km x 10 km national Irish grid squares and further defined within a series of mountain or upland ranges (see also previous national survey).

In addition to above sources, squares were included where recent occupation by hen harrier during the breeding season was known from other reliable sources. Such sources included supplemental records from 2006 to 2021 provided by the Irish Raptor Study Group (IRSG) annual monitoring scheme, the NPWS' species database, BirdWatch Ireland (BWI) raptor sightings database, ecological consultant data primarily from reports for wind energy developments and Environmental Impact Assessment Reports (EIAR) and a review of hen harrier records from the Breeding Bird Atlas data (2007 to 2011 inclusive; Balmer *et al.,* 2013). In addition, squares within the historical range of the species and/or known to contain suitable nesting habitat were also included.

This yielded a total of 327 10 km squares that were known to previously support breeding hen harrier and/or suitable breeding habitat in the Ireland during the period 1998 to 2021. The squares were prioritised, by prior known breeding status (see below; Appendix 6), for survey coverage and allocated amongst surveyors as follows:

(i) 105 'green' squares where breeding had been confirmed (see Barton *et al.,* 2006; Ruddock *et al.,* 2012; Balmer *et al.*, 2013; Ruddock *et al.*, 2016) in the period 1998–2021;

(ii) 28 'yellow' squares where breeding had been recorded as possible (see Barton *et al.,* 2006; Ruddock *et al.*, 2012; Ruddock *et al.,* 2016) in the period 1998–2021;

(iii) 129 'orange' squares in which hen harrier had been sighted in the period 1998–2021 and/or where suitable habitat was recorded; and

(iv) 65 'red' squares which had no historical hen harrier sightings, but which contained known or potentially suitable breeding habitat.

Geo-referenced OSI 1:50,000 maps and aerial photographs for each of the 10 km survey squares survey were digitised using ArcGIS 10.8 and provided to surveyors. The maps included the OSI 1:50,000 background showing habitat, contours, and a labelled 1 km grid layer to allow calculation of spatial references for sightings, nest locations *etc.* derived from the field maps. The aerial photographs (taken in 2018-2021) showed in further detail the extent of forest boundaries and allowed discrimination between improved grassland and unimproved grassland or moorland and afforested habitats.

The names and contact details of potential surveyors were derived from the contact databases of regional hen harrier researchers, the NPWS staff, the Irish Hen Harrier Winter Survey volunteers, Golden Eagle Trust staff and members, IRSG members and volunteers, BirdWatch Ireland staff, members, and volunteers, ecological consultants, and other independent raptor surveyors. Workshops were publicly advertised for people to join the mailing lists and participate, and all survey planning and storage of information was done in compliance with organisational data management procedures. Surveyors were invited to participate in the survey and also to attend training workshops via email and telephone contact. Online workshops and training events were undertaken to disseminate standardised fieldwork methods, distribute maps and aerial photographs and allocate survey squares and field-based training sessions were undertaken as required; group visits were also undertaken during the survey season.

2.3 Defining survey areas

The survey areas were defined by the Irish 10 km grid squares (see Figure 1) and included for selection based on previous records of breeding hen harrier and/or containing suitable breeding habitat. Prior to commencing the survey, surveyors used maps and aerial photographs of each 10 km grid square 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 or walking through the square to "ground-truth" likely breeding habitats and vantage point locations.

As per the approach taken in previous surveys, 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). The following areas were classified as unsuitable habitat and were excluded on maps and from further survey effort (see Hardey *et al.*, 2009; 2013):

- Ground above 600 m;
- built-up/urban areas or within 100 m of occupied farms and dwellings;
- improved pasture and arable farmland; the interior of unbroken, closed-canopy forest blocks;
- sheep-walk (*i.e.* enclosed or unenclosed areas of heavily grazed sheep pasture); 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.

Particular attention was paid to:

- heather moorland which contains stands of deep (usually >0.4 m tall), well-drained heather with more than 50% cover;
- areas with good all-round visibility such as slopes and river valleys;

- deep heather areas within forest clearings;
- forest rides, and pre-thicket stage forest; and
- heather at the edges of forest plantations.

The latter category is usually found where livestock are excluded by fencing associated with afforestation and/or unplanted areas within the forest ownership boundary. Grass-dominated and degraded moorland that contained patches of deep heather or other shrub cover were also surveyed. Other shrub-dominated areas such as river valleys, abandoned fields and bogs with scrub cover were included as potentially suitable habitat for hen harrier in the survey. Pre-thicket coniferous forests were surveyed, and particular attention was paid to areas where forest compartments are characterised by prolific shrub layers. In Northern Ireland, tree-nesting hen harrier have been recorded (Scott, 1991). However, in Ireland mature coniferous forests were only surveyed as part of the 2022 survey where hen harrier observations were regularly associated with post-thicket stage plantations since harriers will often nest in rides or open lacunas within mature plantations. Tree-nesting hen harrier have not been recorded in Ireland and this behaviour appears limited to Co. Antrim only.

In addition, areas of scrub (*e.g.* willow and bramble), often on the edges of moorland or bog, were surveyed for occupancy by hen harrier. Suitable habitat within all survey squares (see Section 4.2) was preferably to be visited on four occasions between late March and the end of July, and three visits was the minimum required.

2.4 Hen harrier field surveys

Surveys in 2022 followed the same methods prescribed for previous national surveys. The surveys involved fixed vantage point methodology following prescribed visit schedules observing suitable habitats. Two visits to establish territorial occupancy were required, with the first visit to occur between late March and mid-April and the second between mid-April and mid-May.

These two visits were the most important as this helps identify where the hen harrier territories may occur. A third survey visit was recommended (but not essential) between 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 visit was required between late June and the end of July to confirm nest activity and whether fledged young had been observed to establish breeding outcome.

These survey visits were timed to reflect the seasonality of the hen harrier breeding activities (see Table 2) and includes the periods of territorial display/mate advertisement, incubation, nestling and fledgling periods (Hardey *et al.,* 2009). The additional visit between late May and late June was to increase the likelihood of detecting a nest location (Hardey *et al.,* 2013) when valuable data can be obtained via hen harrier sightings (see Appendix 1).

2.5 Data recording and data entry

Surveyors were tasked to record key data including contact information; survey effort (location & duration); hen harrier observations (date, time, location, behaviours & habitat); other priority bird species (*i.e.* other raptor species; breeding wader species; red grouse) observations (location & behaviour) and any observed pressures and threats to the harrier in the survey area.

Where available, surveyors were also provided with additional information including any previously used vantage point locations, previously defined suitable habitats, and historical hen harrier sightings from previous national surveys. Surveyors were advised that the habitats and/or habitat suitability may have changed since the previous surveys and similarly any hen harrier may have moved since previous surveys or visibility of vantage point locations may

have changed since previous surveys (*e.g.* increased forest height). It was outlined to surveyors that it was important for them to familiarise themselves with the suitable breeding habitats in the chosen 10 km square(s) and survey all areas that contain suitable breeding habitat for hen harrier.

Surveyors utilised the provided maps and aerial photograph of the allocated 10 km square(s) and used a different map and recording form for each visit to an area of suitable habitat to record the surveyed areas and the locations of hen harrier sightings and/or nests. The key tasks for surveyors prior to and during the field survey were to familiarise themselves initially with the field map, suitable hen harrier habitats, main roads, and potential vantage point locations (such as elevated hills or topographical features). Aerial photographs assisted with the exclusion and mapping up of unsuitable habitat prior to first visits, but surveyors were also made aware these photos may have been taken a few years earlier and some habitat changes may have occurred. Subsequently, during the first field visit, any further unsuitable hen harrier habitats were marked, and mapped accordingly on field maps.

During vantage point watches, surveyors marked the area visible during observations, and vantage point grid references were recorded in the main recording form. Where nest areas were located, surveyors marked these with an X on the map and/or provided a grid reference, based on the estimated nest site location derived from their behavioural observations. Surveyors were advised to complete the survey form during each vantage point watch and finalise forms at the end of the survey day. Surveyors were required to submit nil return sheets even if there were no sightings, and to record all survey effort details, habitat suitability, activities, threats, or pressures on the habitat for nesting hen harrier.

Surveyors were also required to record data in a standard way on either hard copy forms, Microsoft Excel data forms or through a Survey123 online portal. Records derived from vantage point watches and/or casual sightings were recorded throughout the survey period. All survey data entry forms captured the same data (see Table 5). Casual sightings, which are ad hoc observations seen by observers out with a timed vantage point survey, of hen harrier in squares were also welcomed and were submitted on a recording form for the relevant 10 km square as casual sightings.

Surveyors documented pressures and threats using standardised criteria (see Appendix 2 & 3), as per previous national reporting under the EU Birds Directive (*i.e.* Article 12) (see Ruddock *et al.,* 2016) and although an in-depth examination/assessment of pressures will not be covered here, summary information is presented in the report.

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

As detailed in previous national surveys (Ruddock *et al.,* 2016), territories, *i.e.* areas of suitable habitat, were all classified according to observed breeding activity as ‘confirmed’, ‘possible’, ‘seen’ or ‘not seen’. To ensure comparability, the same criteria were used for these categories as in previous surveys (see also 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 territorial home range. A territory was considered to be ‘single occupied’ if only one bird had been observed and this individual could be excluded from belonging to a neighbouring territory by independent observations (or by the absence of a known neighbouring territory).

Where a territory was classified as confirmed or possible despite only a single bird having been recorded during observations, it was deemed to be either a confirmed breeding pair (*e.g.* where only a female was observed carrying food to an active nest and no male was seen; see Table 4) or a possible breeding pair (*e.g.* male bird seen displaying on multiple occasions and could be discriminated from separate territories; see Table 4). The survey co-ordinators analysed all raw data provided, with a view to ensuring independent territories were correctly identified and/or where necessary, clarified the status of the territory with regional co-ordinators and directly with surveyors.

The key criteria used to classify status were the display of territorial and/or breeding behaviours indicative of breeding and the repeated presence of birds at/near the same location. This minimises the risk of over-estimation of breeding activity that would occur if sightings of foraging activity or birds that were only casually, or temporarily, present in an area were included. Throughout the report, these territorial classifications are termed 'confirmed' or 'possible' breeding pairs.

National and regional population estimates for breeding hen harrier were derived by adding the total number of confirmed territories to the number of possible territories to obtain minimum and maximum population estimates *i.e.* the range of confirmed to confirmed + possible territories. Where estimates were available from the 1998–2000 (Norriss *et al.,* 2002), 2005 (Barton *et al.,* 2006), 2010 (Ruddock *et al.,* 2012), and 2015 (Ruddock *et al.,* 2016) hen harrier surveys, the national and regional population changes were examined by calculating the percentage change in the estimates across the five surveys. Additional estimates of national population change were derived by comparing the total number of pairs found in the subset of squares surveyed during the previous national surveys and held in the NPWS 1998–2005 database (Norriss *et al.,* 2002; NPWS, unpublished data).

In this report, three separate subset analyses were undertaken to compare the hen harrier numbers in; (i) squares surveyed in both 2022 and 2015; (ii) squares surveyed in 2022; 2015; 2010 (iii) 2022; 2015; 2010 and 2005; and (iv) the subset of squares surveyed in all five national survey periods 2022; 2015; 2010; 2005 and 1998–2000. The use of such subset analyses reduced the risks of biases created by changes in survey effort and survey areas over time and allows direct comparison of changes between survey periods. Despite survey effort and survey area increasing over time, total numbers of squares covered in each of the subset analyses has declined (i: n = 212; ii: n = 125; iii: n = 105; iv. n = 74). Nonetheless, this subset analyses allows for the most comparable estimates of change, *i.e.* increase or decline, over time.

Whilst breeding pairs in the national surveys are defined based on categorical (behavioural) observations, to provide comparison between survey years, the mid-point value of each of the survey ranges ('confirmed pairs' to 'confirmed + possible pairs') was also used to establish any increase or decrease in pairs between surveys. Mid-point values can be used in population estimates (Anthony *et al.,* 1999) to compare 'calibrated' figures, particularly where effort varies between surveys (Cao *et al.,* 2008). Therefore, no weighting of this mid-point estimate was given to the discrete categorical classification of breeding pairs, but rather it provides a further comparison of population estimates between surveys. To identify high density areas, the number of pairs within each 10 km square was reviewed and classified as a 'high density' square where a minimum of three confirmed or possible territories were recorded following the methods of Barton *et al.,* (2006).

2.7 Population estimates, population changes and habitat composition within SPAs

Estimates of population change were calculated, where possible, for the six breeding hen harrier SPAs. The areas that were surveyed during both the 2005 (pre-designation); 2010; 2015 (post-designation) and 2022 surveys were identified, and the numbers of breeding pairs found were compared between the four surveys. This was achieved, firstly, by comparing the 10 km square summaries for each of these areas between the four surveys. Secondly, to increase the accuracy of the estimates, a point feature database was created in ArcGIS 10.8 of all confirmed and possible territories recorded in the survey and calculating the number of territories within the polygon (downloaded July 2023) of each SPA boundary.

Territory locations for this analysis were plotted at a six-figure grid reference resolution, if the nest was located and at a four-figure grid reference resolution if no nest was located and the area of key breeding behaviours was plotted within a specific 1 km square. That is, the territory is plotted centrally by convention *i.e.* centrally in the 1 km square of breeding activity. Due to

the spatial error associated with plotting such grid references, where territories were near 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 100 m of the boundary for six figure grid references and within 1000 m of the boundary for a four-figure grid reference. The number of breeding pairs in 2022 in each SPA was also compared to the population counts used to identify the candidate SPAs selection in 2007 (see Norriss *et al.,* 2002, Barton *et al.*, 2006) and which were subsequently designated as SPAs.

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

2.8 Breeding outcomes and habitats utilised

The breeding activity at nest locations was established through behavioural observations from vantage points at a distance from nest sites (Hardey *et al.,* 2006; 2009; 2013). Nest visits were not required as part of the survey effort.

Behavioural observations were used to infer the status of nesting attempts as to whether incubation had started. That is, before incubation begins, females typically do not fly from the nest to receive a food-pass from the male, and do not return to the nest directly after feeding. After incubation has begun, however, females tend to fly directly from their nests to receive food-passes, and fly back to the nest after feeding, often carrying nest material. Behavioural evidence was also used to infer hatching, after which females (and, later on, males) deliver prey directly to the nest. The female usually removes prey remains from the nest following feeding until the young are well-feathered and approaching fledging. Therefore, post-season nest visits can also be useful in establishing breeding outcome (Hardey *et al.,* 2009). NPWS-licensed surveyors visited a sample of nest sites after the nests were no longer in use to establish status and/or location information. Nest visits during active breeding efforts were not undertaken during 2022 and to avoid potential disturbance (Hardey *et al.,* 2006; 2009; O'Donoghue, 2010; Hardey *et al.,* 2013).

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

Where nest locations were identified, habitat was broadly classified within 100 m of the nest as one of the following: heather/bog; first rotation forest; second rotation forest; failed forest; scrub (where isolated from plantation forest); mature forest (*i.e.* tree nests), or unknown, where the precise nest location was not explicitly identified.

3. Results

3.1 Survey implementation, coverage, and data submission

A range of online and field-based training workshops were undertaken for the survey to recruit surveyors and to ensure a minimum standard of survey experience and knowledge across all surveyors before its commencement. There were more than 500 potential participants contacted and invited to participate from the respective organisations (IRSG, BWI, GET and NPWS). Relevant information about the training, workshops, and the potential 10 km squares for survey, was published on the project website (www.irishhenharriersurvey.com). The details of the survey were also shared across social media and email platforms to reach a wider network of potential surveyors across Ireland.

The training workshops took place online on 15 March, 22 March and 26 March 2022. A total of 176 people registered for both the online training events and to indicate their willingness to participate in covering the various 10 km survey areas. Subsequent to the workshops, 155 participants registered to undertake a survey square. Following the collation of survey data, an additional 74[1] surveyors submitted supplementary 10 km records and/or casual sightings. A total of 249 observers contributed to the survey which compares to a total of 259 participating during the 2015 survey.

In order to minimise the duplication of effort, across the country, co-ordinators were allotted to three respective sub-regions, as utilised in 2015 (see Figure 1). Respective co-ordinators undertook the liaison with surveyors directly in each of those regions. Regular team meetings between the regional co-ordination teams consistently reviewed survey coverage and square allocations throughout the survey season to maximise allocation of squares and to identify any gaps in coverage that would need to be addressed.

The Hen Harrier European Innovation Programme (HHP)[2] monitoring team continued the survey of the SPAs during 2022, while volunteers and other surveyors focused on areas outside the SPAs. The Northern Ireland Raptor Study Group (NIRSG) assisted in covering 10 km survey squares that included parts of Northern Ireland, with participation from an additional 23 surveyors. The NIRSG also undertook to survey the Northern Ireland population to inform a wider All-Ireland population estimate.

Data from the 2022 survey were inputted to the bespoke Survey123 ® data portal that was developed for the purposes of the survey. Data submissions were requested on or before the 31 August 2022, but all required final submissions were not received until 24 February 2023, with further lengthy scrutiny required on foot of final submissions. The allowance of time and facilitation of extended data submission periods is important to ensure all collected data is obtained and adequately incorporated within the final survey report and outputs. Several hundred hours of work were undertaken by the regional co-ordination teams to obtain data submissions and to input any hard copy data received into the standardised Survey123 data portal.

For the 2022 survey, the survey squares, including those used in 2015 (n=308) were reviewed and 327 10 km squares were initially identified as potentially suitable and/or known to be within the historical breeding range of the species. Nineteen of these 10 km squares were defined as unsuitable or no longer suitable for hen harrier and were excluded from overall survey effort. Casual sightings were received for three of these 19 excluded squares and these sightings

[1] 27; 46; 21 observers from the respective workshops

[2] The HHP was funded by the Department of Food and Marine (DAFM) to deliver a results-based landscape-scale habitat management programme for hen harriers and monitored the six hen harrier Special Protection Areas (SPAs) in Ireland annually between 2017 and 2022.

indicated two of the 10 km squares had hen harrier seen and/or sightings were made outside of the breeding season and were known wintering sites.

Therefore from the 327 squares as potentially and/or historically suitable, 46 were not suitable at the time of the survey for breeding harrier with an additional 26 squares considered to be of marginal suitability and/or rendered mostly unsuitable during the survey year by virtue of recent burning activity and therefore unsuitable habitats within squares was not surveyed further (see Appendix 6). There were 272 of the 327 squares initially allocated for coverage (*i.e.* 83%), of which 31 squares were defined as unsuitable and/or no-longer suitable for breeding hen harrier. Nineteen of the allocated squares were considered to have marginal suitability of breeding habitat for hen harrier.

The total allocation of 272 survey squares to all surveyors from the known / recent / likely breeding range of hen harrier was broken down across the following:

- 101 of 105 (95%) 'green' squares (see Methods; Figure 1)
- 26 of 28 'yellow' squares (93%)
- 101 of 129 suitable 'orange' squares (78%) and
- 44 of 65 of suitable 'red' squares (68%).

Final data submissions obtained information from 258 squares within the priority allocation as 'green' 100 (95%); yellow 24 (86%); orange 93 (72%) and red 41 (63%) respectively.

Levels of coverage were comparative to the 2015 survey (which achieved 100%; 82%; 73%; 67% of green, yellow, orange and red squares respectively) and higher than 2010 survey (85%; 52%; 51%; 34%). There was a notable increase in the assessment by surveyors of squares categorised as unsuitable or of marginal habitat suitability (22%) in 2022 compared to the 2015 survey (14%). Consequently, these squares were not typically covered extensively during the survey, which decreased apparent survey coverage within all the priority categories.

Within each of the above priority categories there were 7; 2; 48 and 15 squares considered to be unsuitable or of marginal suitability during the 2022 survey which reflects an apparent deterioration of habitats since the previous survey (Appendix 6). This included nine squares (3%) which had previously (2015) held confirmed and/or possible breeding pairs of hen harrier. Sizeable proportions of the orange (37%) and red (23%) squares were defined as not suitable for hen harrier.

Data was received for 13 additional 10 km squares in 2022 that were not identified within the original survey planning. Most of these records were derived from casual sightings although two squares that were not previously covered in national surveys held a single confirmed pair each of hen harrier. Data was not received for 33 10 km squares (see Appendix 6) in time for inclusion in analyses, although it is understood that survey coverage was undertaken and that no further pairs of hen harrier were encountered during the completed visits and/or habitat was no longer suitable for the hen harrier.

3.2 Survey effort and observations

A minimum of 3,279 visits were undertaken across the survey areas. This is similar to 2015 (3,296; Ruddock *et al.*, 2016) and higher than 2010 (2,712; Ruddock *et al.,* 2012). Records received spanned from 4 January 2022 to 23 January 2023. Most visits were conducted during the breeding season (1 March–30 August; n= 3,011) whilst the remainder were undertaken prior to the survey commencing (n = 254; 8%) or after the breeding season *i.e.* post August (n = 14; 0.5%).

The standardised data submissions via the Survey123 portal increased the analytical and cross-referencing ability of the co-ordination team in order to follow up on data submissions and surveyor records. Hard copy and/or excel data records and maps were digitised by the regional co-ordinators within the online portal system.

Survey visits within the survey schedule (Table 1) were completed as 1 March – mid April (Visit 1: 59%; n = 777; range 0–30 visits); mid-April – mid-May (Visit 2: 62%; n = 947; range 0–23); mid-May – mid-June (Visit 3: 42%; n = 581; range 0–18) and mid-June – end July/August (Visit 4: 53%; n = 706; range 0–15).

Survey effort comprised 7,704 hours, which is more than the 7,225 hours during 2015 and considerably greater than 2010 (4,074 hours). Survey visits were conducted between 0515h and 2300h and surveys ranged in duration from 5 minutes to 15 hours 45 minutes, with an average duration of 2 hours and 32 minutes.

Records ranged from null (*i.e.* none seen) to six birds per individual sighting in 2022 and a total of 1,872 hen harrier sightings made during the survey. This number of sightings, despite similar survey efforts, is lower than previously in 2015 (2,222) and therefore a 16% decrease in sightings overall was recorded. Most of the detections in 2022 were males (73%; n = 1117) followed by females (41%; n = 620); sub-adult males (2%; n = 37) and juveniles (6%; n = 98). Like previous surveys, habitat classifications and behaviours were recorded for each sighting, as well as observations of pressures and threats. No further interpretation of the breakdown of these sightings results (by habitat or behaviour or pressures) is being undertaken within this analysis (see Appendix 1 for summary sightings table for 2022 and previous national surveys).

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

3.3.1 National status

The 2022 survey identified 85 confirmed and 21 possible territorial hen harrier sites (85-106) in Ireland. This represents a decline from all the previous national surveys including 2015 (108–157); 2010 (128–172); 2005 (132–153; and 1998–2000 (102–129) (refer to Table 11). The percentage decrease, based on maximum population estimate (confirmed + possible) from each of these surveys is -33% (since 2015), -38% (since 2010), -31% (since 2005), and -18% (since 1998-2000) respectively meaning the population has declined from all previous estimates and now comprises only around 100 pairs (Table 6).

A review of mid-point values (see Ruddock *et al.*, 2016) reveals that, between the 2022 and 2015 surveys, the population has declined by 28% (Figure 3; Table 6). Survey effort was relatively similar during 2022 and 2015, therefore reducing the likelihood of bias regarding estimates of population size or change between surveys.

In 2022, 48 10 km squares were confirmed with breeding hen harrier and a further 13 10 km squares contained at least one possible breeding hen harrier territory. The total breeding range therefore spanned 48–61 10 km squares, a decline from 2015 (62–84 squares) and more akin to the earlier survey results from 1998–2000 and 2005 (Table 7). Also in 2022, 64 squares were classified as ‘seen’ and 126 squares classified as ‘not seen’ and various regional changes are evident across the species distribution plotted from 2022 (Figure 4) and compared to previous surveys (Figures 6–9; Ruddock *et al.*, 2016).

The density and number of hen harrier recorded within each 10 km square varied between 1 – 10 confirmed territories and between 1–2 possible territories. Most confirmed breeding 10 km squares contained between 1 and 4 territories and only a single 10 km square contained more than four, with a remarkable 10 territories recorded. Nationally, the density of territories per 10 km square appears to have largely decreased (Figure 10) and various regional changes are evident across the species distribution plotted from 2022 (Figures 6–9; 11) and compared to previous surveys (see Ruddock *et al.,* 2016).

3.3.2 Subset Analysis (1998/2000 - 2022)

Various subset analyses of the 10 km squares that were covered in each sequential survey, allows for like-for-like comparisons to examine range trends and population change over the short term (2022–2015), medium term (2022-2015-2010), longer term (2022-2015-2010-2005) and since national surveys began (2022-2015-2010-2005-1998/2000). Each of these comparative analyses show declines across the species range, including up to the 2022 survey. Based on total population estimates (confirmed + possible), these declines amount to

- 35% in the short term (2015);
- 34-46% (2010) in the medium term;
- whilst longer term the declines are between 37% and 48% since 2005; and
- between 37% and 59% since national surveys commenced (1998/2000).

Overall, since the first national survey of 1998/2000, the population has decreased by up to 59% across those consistently surveyed areas and includes losses across most regional populations (see Table 9).

3.3.3 Regional changes

The various regional populations across Ireland have been monitored and reported on since the first national survey in 19982000 (Norriss *et al.,* 2002). These areas have fluctuated between different national surveys with declines and increases in some areas between survey years and various regional extinctions, which appear to have taken place during the past 25 years.

At least 15 of the regional populations, (see map in Barton *et al.,* 2006) scattered across the island, have seen further declines based on comparison of the 2015 and 2022 figures. Several of these defined regional populations (see Norriss *et al.,* 2002) includes lands within the now defined SPAs for breeding hen harrier, particularly the Devilsbit, Slievefelim, Silvermines, King Hill; the Slieve Aughties; the Slieve Blooms; the Stack's, and Glanarudderies, Knockanefune, Mullaghareirks, north of Abbeyfeale (see Section 5.4). Some of the regional populations have declined by more than 25% and up to 100% in some cases, such as at the Nagles and in several other regions where no pairs were recorded in 2022 (Table 9).

Declines of more than 25% were recorded within the Ballyhouras; Blue Stack Mountains, Pettigo Plateau & south Donegal; Devilsbit, Slievefelim, Silvermines, King Hill; Galtys; Knockmealdowns, Kilworth, Comeraghs; Leitrim, Slieve Rushen & Cavan; Longford, Roscommon; Nagles; Slieve Aughties; Slieve Bernagh to Keeper Hill; Slieve Blooms; west Cork; and Wexford.

Some of the regional populations appear relatively stable since the last national survey and/or exhibit smaller declines (10-25%) within the range and since the previous national survey including east Cork & Waterford; north & west Clare; Slieve Beagh; and Stack's, Glanarudderies, Knockanefune, Mullaghareirks, north of Abbeyfeale.

During 2022, three areas have exhibited small increases since the 2015 survey which includes Boggeraghs, Derrynasaggarts (1-3 pairs); West Kerry (1 pair) and newly identified areas since 1998-2000 *i.e.* beyond the original survey range in Other Areas (1-2 pairs; see Table 9). Single sightings of flying ringtail[3] hen harrier within the north-west (north of Nephin Beg) and Wicklow (north-east of Lugnaquillia) were recorded during the breeding season. Neither of these exhibited breeding behaviours or were recorded subsequently, despite extensive prior and follow up-surveys across the range of suitable habitats in these two regions; records were defined as 'seen' only.

[3] *i.e.* either females or juveniles, both with white rump and dark rings, often referred to as ringtails

Some of the known historical regional populations appear functionally extinct for breeding purposes including Castlecomer, Blackstairs, Kilkenny; Curlew Mountains; Inishowen Peninsula; Kildare; Longford-Roscommon; north-west; Ox Mountains; west Cork; Wexford and Wicklow Mountains although some do contain wintering hen harrier. In 2022, there was confirmation that some regional populations held no breeding pairs (see Table 9) and have not done so for the last number of national surveys. No known breeding hen harrier has been recorded for the past 10 to 20 or so years in Castlecomer, Blackstairs, Kilkenny; Curlew Mountains; Inishowen; Kildare; the north-west; Ox Mountains; and Wicklow Mountains.

3.4 Population estimates, population changes and habitat composition within SPAs

The 10 km squares across the six breeding SPAs held a recorded 48 – 55 breeding territories which is fewer than previous surveys 2015 (55–77), 2010 (69–94) and 2005 (85–93). This is an overall 41% decline in breeding territories since these sites were identified for designation. The previous change between the third and fourth national surveys was 17% (2010 to 2015; Ruddock *et al.*, 2016) and subset analyses of changes indicate greater declines showing 29% between 2022 and 2015 and 41% between 2022 and 2010.

Within the now defined SPA boundaries, there are fewer pairs present in 2022 than at the times these sites were proposed for designation (2007), with the 2022 data highlighting a substantial decline with just 38–43 territories remaining. This is 26 fewer pairs for the SPAs than in 2015 (51–69) and a decline of 38% with an overall loss since 2005 (82–94) of 51 pairs which is a decline of 54% (Table 10). Over half of the SPA population of hen harrier in Ireland has been lost in the 15 years since these sites were proposed for designation in 2007 (NPWS, 2022).

Hen harrier populations have declined in five of the six SPAs (between 20–80%) since the 2005 survey and only one site, the Slieve Bloom Mountains has maintained a broadly stable breeding population of hen harrier since the 2005 survey, with fluctuations of no more than one pair across the subsequent national surveys (Table 10).

In 2022, within proximity to the SPAs (500 m and 2 km respectively), there were between four and seven pairs of harriers located. The Slievefelim to Silvermines Mountains SPA had several pairs that were located between 1.8 km and 3.7 km beyond the SPA boundary (4-5 pairs). These pairs may have displaced or moved from within the SPA itself to the wider area beyond the boundary since the previous national surveys. At Sliabh Beagh SPA, other pairs were located across the border in Northern Ireland (2-3 pairs within 2 km in the Slieve Beagh-Mullaghfad-Lisnaskea SPA). The Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPA also held a wider connected breeding population (six pairs) in areas adjacent to the SPA boundaries, ranging from just 20 m away to 1.6 km.

3.5 Breeding outcomes and habitats utilised

3.5.1 National assessment

Observations of breeding habitats and breeding outcomes were collected during vantage point surveys. No nest visits were conducted during the breeding season by observers as part of the survey. Nor were the coordinators aware of any research involving nest visits during 2022. A small number of licensed post-season visits were conducted. Behavioural observations by surveyors provided informative sightings such as repeated nest visitation (with or without prey) by adult birds; prey delivery to nests and remote counts of fledged chicks (see Methods) to establish stages of breeding and outcomes.

Once territorial behaviours by harriers were observed, a high proportion of nest initiation behaviours (89%; n = 76 of 85 confirmed pairs) including birds observed visiting nests and

nest building / egg-laying was subsequently confirmed. A small proportion of confirmed breeding pairs held a territory but did not exhibit behaviours consistent with pairs that had clutches or were brooding young chicks (5%; n = 4 or it was not known if a nest was initiated (6%; n = 5). Based on behavioural observations *i.e.* delivery of prey to an identified nest site, there were a minimum of 65 pairs (76%) which hatched nestlings during the 2022 breeding season. This reveals conversely that a lower proportion (24%) of sites (n = 20) failed to hatch and/or there was no certainty of the stage of subsequent failure *i.e.* at egg or nestling stage. There were no brood sizes counted within any nests during the 2022 survey season since no nest visits were undertaken or submitted to the databases.

Breeding outcome was defined as a binary output (failed or successful) depending on whether chicks were fledged. Fledging was verified and/or observed at 37 (44%) identified sites which represents an overall detected rate of success of nesting pairs as 49% (37 of 76 pairs). For the pairs with confirmed fledging counts, there were between one and four chicks fledged (average 2.0 fledged young per successful nest) and a total of 75 young were recorded to be fledged from 37 pairs. This equates to an average of 0.9 young fledged per confirmed pair and 1.0 young per nesting pair or 0.7 young per breeding (confirmed + possible) pair.

Based on field observations of those nests active for numerous weeks *i.e.* with adults feeding young in the nest, the proportion of nests which failed prior to fledging was relatively high (40% *i.e.* 26 of 65 pairs). If we include the 21 possible records that failed to produce any chicks during the 2022 season, then overall breeding failure rates are at 60% (64 of 106). It is acknowledged that specific nest monitoring, which is required for robust data on breeding performance and the factors, which may cause, or influence nest failure was not conducted in this survey. However, the suspected or observed reasons for failure at nests in 2022 included:

- forestry management (harvesting) activity and associated human and vehicular/machinery-related disturbance;
- human (walking) disturbance;
- dog walking (on and off leads);
- off-road trail motorbike (scrambler) disturbance;
- predation (mammalian);
- predation (dog);
- predation (avian); and
- digging (turf / machinery) disturbance.

For confirmed breeding territories, the habitat within which the nest site was located was dominated by:

- scrub habitats (n = 29);
- second rotation forest (n = 16);
- heather (n = 16);
- heather / scrub (n = 13);
- heather / second rotation forest (n = 6);
- scrub / second rotation forest (n = 3);
- clearfell (n = 1); and
- heather / failed forest (n = 1).

Breeding success was similar across the main habitats where nests were located *i.e.* heather dominated (45%) and scrub dominated (42%) and in second rotation / forest dominated habitats (41%) albeit sample sizes were small across all these categories, given the extent of the overall decline in the national breeding population (see Appendix 4).

3.5.2 SPAs assessment

In the SPAs, there were 38 confirmed pairs of which 15 were successful (39%) and the remainder failed to fledge any young (61%). The successful breeding sites within the SPAs fledged a total of 31 chicks, which accounts for 61% of all recorded fledged young in Ireland for 2022. The SPA with the highest number of fledged chicks, and 65% of the SPA network total, was the Stack's to Mullaghareirk, West Limerick Hills & Mount Eagle (n = 20 chicks from 8 confirmed and successful pairs).

The Mullaghanish to Musheramore Mountains SPA and Slieve Beagh SPA failed to fledge any chicks during in 2022 from one and 2-3 pairs respectively and Slievefelim to Silvermines Mountains SPA fledged only a single chick from one nest site.

The Slieve Bloom Mountains SPA and Slieve Aughty Mountains SPA held three successful nest sites each and fledged a total of six and four chicks respectively in 2022.

Within the SPAs, nesting habitats of confirmed pairs were predominantly in:

- scrub (n = 13);
- heather (n = 9);
- second rotation forest (n = 7);
- heather/scrub (n = 5); and
- heather/second rotation forest (n = 4), although these varied across the SPAs.

As set out in the results above, the numbers of pairs nesting in scrub habitat in 2022 in SPAs and the wider countryside, reflects an increasing occurrence of the use of this habitat within hen harrier breeding sites.

At least eight of the SPA nest sites were recorded to reach late nestling stage. Some nests were known to be within days of fledging young *e.g.* chicks observed jumping up to meet parent birds from the nest, and yet subsequently failed, most likely due to predation. Sudden failures observed at this late stage of the nestling stage are typically due to predation. Predation appears to remain a key cause of failure for this species including in the SPAs. Other disturbances recorded within the SPAs included off-road motorbikes; recreational walkers and unleashed domesticated dogs which were thought (by NPWS rangers) to have killed nestling harriers prior to fledging within the Slieve Blooms.

4. Discussion

4.1 Survey implementation, coverage, and data submission

Survey delivery was maximised by an experienced co-ordination team, the majority of whom were involved in the previous (2015) national survey, thus allowing the augmentation of overall survey coverage during 2022. The partnership of co-ordinating organisations (IRSG, GET & BWI) and NPWS has delivered a national survey which has hugely benefited from the survey proficiency and survey management experience of the collective stakeholders. In particular, the provision of substantial volunteer effort through leveraging a wide network of surveyors, and in the cost-savings accrued via pooling of resources and effort. Lessons learned from the 2015 survey were implemented for the 2022 survey, which included using regional co-ordinators to oversee coverage zones (Figure 1) to support the increased efficacy of survey deployment, fieldwork, follow-up, communication, and collation of data with the surveyor network.

In 2022, the total numbers participating in workshops, training and in the survey itself were similar to 2015 (249 compared to 259). Workshops were given online, which offered high levels

of national coverage and greater resource efficiency compared to in-person workshops operated for previous surveys. Online training formats have become increasingly useful and applicable for spatially dispersed working teams since the Covid-19 pandemic. As a result, greater online and remote access working is evident, and some efficiencies were evident in taking this approach for the national survey. Subsequent field-based training and survey team visits allowed more personable interaction opportunities with surveyor networks and particularly new recruits.

The IRSG noted that several long-standing experienced surveyors were not able to participate in this survey due to an increasing age profile. Several novel but highly experienced hen harrier surveyors participated in 2022. Many of these novel experts are a product of various university and project-based training (*e.g.* HHP) programmes since the 2015 survey. There were a range of newly-participating surveyors, who were offered additional support, engagement and pairing with more experienced surveyors. The dynamics between national surveys in volunteer participation highlights the importance of training and upskilling of new hen harrier surveyors on an on-going basis for future surveys to counteract turnover and provide legacy of expertise for future surveys. For the national hen harrier surveys, the coordinating organisations and their respective networks contribute, and leverage, a significant volunteer effort comprising around 74% of total survey effort representing a substantial financial resource contribution.

Differing survey effort and/or coverage can complicate both estimates of numbers and/or the veracity of conclusions on any measured changes between years (Lewis & Gould, 2000; Johnson *et al.,* 2019; Steiner *et al.,* 2022). However, the consistency of total numbers of surveyors involved in recent national surveys is reassuring particularly with reference to the comparison of results and findings. Similarly, the extent of coverage of 10 km squares between surveys has been consistently high across the hierarchy of priority squares (green; yellow; orange; red) and, importantly, is comparable between the years of national surveys. For the 2022 survey, there was overall high coverage of priority squares at 95%; 93%; 73% and 71% respectively (see Appendix 6) and compared similarly to coverage in 2015 at 100%; 82%; 73%; 67% and is higher than coverage achieved in 2010 (85%; 52%; 51% and 34%).

Surveyors may be unable to complete all planned survey visits, for various reasons, during a field season. Each co-ordinator encouraged surveyors to engage with others and/or the regional teams to increase the total survey visit coverage. However, some coverage gaps were not known to co-ordinators until after the survey season was completed. Ongoing encouragement to surveyors throughout a field season to complete the 10 km coverage and survey visits remains important for national surveys. The total survey effort is largely comparable between national surveys, which is important for establishing direction and/or significance of changes in hen harrier numbers between survey years.

Since the first national survey (1998-00), there has been an ever-increasing number of 10 km squares added to the list of potential survey squares for hen harrier including 2010 (233); 2015 (308) and 2022 (327). However, an increasing proportion of these squares are subsequently being identified as unsuitable or no longer suitable for hen harrier during subsequent field surveys. This increase in unsuitable squares may reflect further losses and fragmentation of hen harrier supporting habitats. Human-mediated factors including agricultural reclamation, drainage, scrub removal, afforestation and maturation of forested areas were reported as drivers of extensive habitat changes during 2022 and reflected in surveyor observations.

Though these aforementioned changes in habitat suitability of some squares have been observed and verified by surveyors, the habitat change metrics in terms of precise scale and extent have not been measured and is beyond the scope of this survey. Estimates of changes in habitat suitability of survey squares between national surveys are complicated by survey square coverage between years. However, a total of 72 of the 340 (21%) squares initially identified for survey in 2022 were subsequently defined as marginal or unsuitable for breeding hen harrier. In past surveys, these squares would have been identified to contain suitable habitat and/or breeding birds. Examination of habitat changes and losses over time would be best reflected in a specific analysis of the National Land Cover data (overlapping with the core

hen harrier breeding range) and/or repeated surveys of specific site-based assessments such as that completed by Moran & Wilson-Parr (2014) for the breeding hen harrier SPAs.

The complexity of habitat changes over time within the known breeding range of hen harrier requires on-going assessment and periodic review to detect changes in suitability both before, during and after national surveys. For example, for survey squares where habitat becomes unsuitable over time, and these may be subsequently excluded from surveys, the comparability of survey results between years may be affected. Conversely, if habitat improvements were to occur between national survey years, and potentially suitable squares were to be excluded, future hen harrier recovery for these areas may not be detected. Reviews of likely suitability of 10 km survey squares before and during surveys remain a key component of the survey to ensure suitable habitat and range of the species are adequately covered.

The capture of late wintering hen harrier records also adds several squares that do not contain breeding habitats or birds during the breeding season. The addition and subtraction of squares between surveys is becoming a multifarious issue, both prior to and after survey visits, during survey planning and subsequent analysis. That is, some survey effort deployed on squares that may not contain breeding habitats nor birds. Conversely, some previously unsurveyed squares have been found to contain breeding birds in both the 2022 and 2015 surveys.

In 2022, there were two squares which were not previously identified for survey but were found to contain a single confirmed pair in each square. These may be an artefact of displacement from adjacent squares into less suitable habitats and/or habitat improvements and/or demonstrate the capacity for recovery and population increases over time. Thus, the expansion into new survey squares and suitable habitat must remain fundamental in the review, assessment, and survey of 10 km squares covered during national surveys.

Data submission and analysis is a core part of the national survey and data entry portal technology and the improvement of software over time has enabled increased efficiency of data submission. The ArcGIS software and Survey123 portals are robust at data capture and allow ready mapping, interpretation, and analysis. There were minor issues detected with the online portals. A small number of surveyors inputted a spatial location of the data submission location, *e.g.* the vantage point or an office-based grid location, rather than the spatial details of the bird sightings. These were easily identified via the mapping of the sightings and subsequent review of same by survey co-ordinators. This spatial information was checked, validated, and followed up with individual surveyors to capture the required locations. Some mobile devices also allowed the circumvention of the required ‘entry of a grid reference for each sighting’, despite having a requisite data capture box and these examples also required follow up to verify sighting and vantage point grid references. Any online submission process requires robust review procedures and analysis to cross-reference and verify data.

Sighting and effort submissions were streamlined with online portals and analysis of the vantage point and sightings data can take a variable amount of time depending on the level of interpretation required. Analysis of breeding territories, locations and overall determination of breeding status for each territory took until 24 August 2023 to complete, to obtain the requisite clarifications and to establish population estimates, abundance, and distribution.

4.2 Survey effort and observations

Survey effort in 2022 was higher than in both 2010 and 2005 and thus the accuracy of breeding population estimates, and breeding range continues to improve with each national survey. There was a maintained level of high survey square coverage, as per the 2015 survey, with similar numbers of surveyors and survey visits across the national breeding range and a slightly increased number of survey hours (7%) compared to 2015. The consistency of effort enhances the accuracy and comparability of findings within and, between years. Effort may be influenced by the visit schedules (see Table 1), seasonality, repeatability, extent of suitable habitats, number of surveyors and the duration of surveys within individual 10 km squares.

In 2022, of the 254 squares for which data were received, all three requisite visits were completed for 132 (52%) and only 101 of these had all four visits completed (39%). First visits were higher (at 79%) in 2022 than both 2015 (62%) and 2010 (59%) whilst second visits (82%) were broadly on par with previous surveys (2015; 81%; 2010; 81%). More final visits were completed (at 63%) than in 2015 (57%) and 2010 (54%). Although numbers of final visits could be higher to establish final breeding outcomes, the requirement for some of these visits at some sites lessens as the season progresses since they are optional if any first visits have had no detections of hen harrier. A similar proportion of surveyors completed the third visits in 2022 (56%) compared to 2015 (57%) and more so than in 2010 (50%).

The overall status (Table 4) of the 10 km survey squares in 2022, was hierarchically linked to the numbers of survey visits completed, as per previous national surveys (see Ruddock *et al.,* 2016). The average total number of visits for confirmed squares (mean 22.6 visits), was higher than possible (mean 17.6 visits), seen (mean 6.6. visits) and not seen (mean 6.5 visits). It remains essential in future surveys to maintain visit frequency and survey effort to ensure robust conclusions, and confidence in same regarding the final breeding status assessment of pairs within 10 km squares.

With similar survey efforts between the two most recent surveys (2022 and 2015), albeit some 10 km squares were not covered in both years, the observed decline in the sightings of hen harrier is marked. It is recognised that survey effort was lower during the 2010 survey. The total numbers of sightings of birds declined by around 16% across all sex and age classes combined in 2022 comparted to the 2015 survey. For total sightings of females, there was a more striking apparent reduction (620 in 2022 and 1066 in 2015 and 865 in 2010), or a -28 to -72% reduction between 2022 and the previous two national surveys.

More than a 70% decrease in the sightings of females compared to 2015 seems alarming. The numbers of sightings of males between surveys was similar (-0.5%) and/or increased (19%): 1117 (2022); 1123 (2015) and 943 (2010). Sightings of immature males (*i.e.* second or third calendar year birds are readily identifiable with interspersed brown and white mixed plumages) also declined, similar to females, between 2022 (37) and 2015 (120) by -69% and between 2022 and 2010 (50) by -26%. Total sightings of juveniles similarly declined by -74% from 2015 (378) to 2022 (98) and by -11% compared to 2010 (110).

The declines in sightings of females, immature males and juveniles can be a sign of skewed sex and age ratios indicative of small populations under-going numerical and/or range declines and can highlight a severe threat to the population (Venables & Brooke, 2014; Morrison *et al.,* 2016a). There is an apparent male preponderance in the recorded hen harrier population in 2022, suggesting availability of females may be the limiting factor in population growth and/or proliferation and/or expansion (Hunt *et al.,* 2017). Similarly, an absence of juveniles or young birds is indicative of a decline in potential recruits for subsequent breeding seasons. The on-going observed declines in the overall population, and a lack of any potential population growth rate, points to an unstable breeding population. Any recovery would require an increase in abundance of breeding females and young birds to allow for any expansion of breeding territories.

It is widely recognised that delayed maturity and low reproductive rates make raptors vulnerable to high mortality rates, and a wide variety of human-related threats negatively affect their population dynamics and persistence over time (De Pascalis *et al.,* 2020). The recorded changes in observed detection frequency for females and young hen harrier during the breeding season and across their range in Ireland indicates that there may be a sex- and age-biased mortality occurring. This may be mediated via some of the observed threats or pressures such as loss of females and nestlings during nest destruction (*e.g.* through fire or forest clear-felling or nest predation) or perhaps over-wintering mortality (*e.g.* at roost sites), all of which may be leading to a disproportionate mortality of these sex / age classes compared to adult males (Grüebler *et al.,* 2008). Future management and protection measures for hen harrier in Ireland requires efforts to focus on increasing brood success and optimising the survival of females (Newton *et al.,* 2016).

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

4.3.1 National change

Between 2015 and 2022, the national breeding population of hen harrier declined by 33% in total or maximum numbers (*i.e.* confirmed + possible pairs). This appears to be an acceleration of losses and is greater than the 8.4% decline recorded between 2010 and 2015 (Ruddock *et al.,* 2016). Using the mid-point values for comparison between 2022 and 2015 confirms a 28% decline in the population. The maximum population recorded in 2022 is lower than all previous national surveys including 2015 (157); 2010 (172); 2005 (153) and 1998-2000 (129). The mid-point estimate (95.5 pairs) is lower than all previous national population surveys including lower than the population estimate (115.5 pairs) in 1998-2000 (Norriss *et al.,* 2002). The population is now at its most depleted point of the past 25 years.

Previously, Ruddock *et al.,* (2016) predicted that based on declines observed between 2010 and 2015 (estimated as 11.7% every five years or 2.3% annually), there could be fewer than 100 pairs of hen harrier in Ireland within 25 years *i.e.* by 2040. This prediction has since proven to be an underestimate, since the national population has now declined to less than 100 confirmed pairs and by one third overall within just seven years. The prediction at that time assumed that the magnitude of decline would not double again, as it had done over the previous 10 years (2005–2015). There has been no national population growth or stabilisation recorded since 2015. Instead the magnitude of the decline has more than tripled (33%) indicating at least a 4.7% annual decline over a seven-year period 2015 to 2022.

The use of the mid-point values showed an increase from the first national survey to the second and third, and to some extent may be explained by increasing survey effort over time which is a critical determinant in population estimation (Calladine *et al.*, 2009; Symons *et al.*, 2018), including for raptors (Johnson *et al.,* 2019). Total population numbers and mid-point values have declined sequentially since the 2010 survey (including for both 2015 and 2022 surveys). Though both survey coverage and effort across national surveys have been broadly equivalent, the magnitude of the population decline has increased. At the current rate of decline, population extinction could be expected within 25 years and there could be fewer than 50 breeding pairs of hen harrier remaining within the next 10 years.

The specific subset analyses (*i.e.* review of 212 10 km squares covered in both 2015 and 2022), equates to 83% and 79% of the total squares surveyed in those respective surveys. Comparative survey effort for these subsets was equivalent to 7,095 hours in 2022 and 6,554 hours in 2015. The total population change estimation from 2015 to 2022, based on the comparative number of squares (*i.e.* 212 total), shows a higher rate of decline (35%) than the overall direct comparison (33%), with losses of both possible and confirmed breeding territories. For the second subset analyses (comparing 125 squares covered in 2022, 2015 and 2010), declines across all breeding categories ranged from 34% (2022 vs 2015) to 46% (2022 vs 2010). That is nearly 50% of a decline in the comparative subsets over the past 13 years.

Longer-term comparisons over the third subset analyses 2022-2015-2010-2005 (17-year span; 105 squares) further supports evidence of declines, particularly the total number of possible breeding pairs in both 2015 (37%) and 2010 (48%), and 2005 (44%) (Table 8). Some of these observed patterns may be an artefact of a single 10 km square in 2022 that held 10 confirmed breeding pairs, which was surveyed in all survey years. It is also recognised that movements of pairs between 10 km squares may not be reflected in these subset analyses should the surrounding squares not have been covered during one or other of the national surveys. Over the longer term (24-year span) subset analyses, including all five national breeding hen harrier surveys of 2022-2015-2010-2005-1998/2000, the recorded declines using the subset square analyses are relatively stark. These analyses indicate 37% declines from 2022 to 2015 (compared to 33% recorded by comparison of total figures) and declines of

more than or equal to 50% for the other three national surveys (52% in 2010; 50% in 2005 and 59% in 1998-2000) (Table 8).

The observed declines in the national hen harrier population set out above would warrant breeding hen harrier meeting the Red-list criteria, as described in the Birds of Conservation Concern in Ireland (BOCCI; Lynas *et al.,* 2007; Colhoun & Cummins, 2013; Gilbert *et al.,* 2021) *i.e.* "species whose populations have declined by at least 50% over 25 years". In summary, the status of the breeding hen harrier population in Ireland now meets these red-list criteria. The comparable consideration of surveyed squares between survey years, and comparable estimates of the All-Ireland population (Ireland + N. Ireland), should be used to inform the next BOCCI assessment. The hen harrier population has declined by more than 50% within the past 25 years and requires increased and urgent conservation management and implementation.

The range (or distribution) of the species, based on 10 km square comparisons, has contracted since 2005 and is similar to the range recorded in the 1998-2000 national breeding survey. The purported range expansion of previous national surveys now appears to have retracted with declines in the short term (2015; -27%); medium term (2010; -12% & 2005; -8%) and a small difference in the long term (1998-2000; 3%). The reduction in breeding range across Ireland is recorded across the various mountain ranges, with only a small number of new pairs located during 2022 (Table 9).

4.3.2 Regional changes

A range of changes were recorded across the regional populations which are reviewed here. In addition, a series of pressures and threats were recorded by surveyors, which may be operating within the range, or potential range, of the hen harrier in those regions. Whilst a selection of site-specific examples are presented below, the effects may not be limited to those sites and various pressures and threats may also be operating at a national level, but observed across regional areas.

Despite showing increases in previous national surveys, the Ballyhouras population is now lower than the total number of pairs recorded in 1998-2000 and it is evident that a significant population crash (63%) has occurred since the peak in 2005. Surveyors in the Ballyhouras recorded a range of activities (including human recreational activities such as scrambling, mountain biking and forestry management works) which are considered to be sources of disturbance to breeding hen harriers (Carravaggi *et al.*, 2019). The development and spatial planning of new mountain bike track networks and trails for the Ballyhouras should consider hen harrier and other Annex 1 species (peregrine falcon) in their environmental assessments.

The Blue Stack Mountains, Pettigo Plateau and south Donegal population increased by 1100% between 1998-2000 to 2015. Between 2015 and 2022, this former stronghold has now declined by 42%, with a maximum of seven pairs recorded. The border area with Northern Ireland at south Donegal previously held several pairs but total numbers have declined. Furthermore, several known pairs have been reported by surveyors in 2022 to have been likely displaced by recent wind energy developments, including *e.g.* due to works at Meenbog (Co. Donegal) where extensive environmental damage was caused due to peat slippage. These factors are also operating nationally (see NPWS, 2021) and across various regions. Invasive species, particularly rhododendron, are damaging extensive areas of previously suitable breeding habitat for hen harrier in this region.

The Boggeraghs, Derrynasaggarts region (Co. Cork) has maintained a similar population throughout the sequence of national surveys with a small increase recorded up to 2010, but since then, similar numbers remain present, with a marginal increase recorded in 2022 since 2015. In this region, surveyors have indicated that breeding pairs are likely to be influenced and/or disturbed by dog walking (in close proximity to known and past nest sites), proposed windfarms, agricultural reclamation (scrub removal), over-grazing and maturing conifer forests. The latter contributes to high levels of inter-specific interaction with buzzards which are

associated with the mature conifer plantations and therefore habitat changes may be causative in the displacement of hen harriers through the loss of suitable habitat for one species which favours another *i.e.* the buzzard.

The Castlecomer, Blackstairs, Kilkenny region did not hold any pairs of hen harrier in the current survey nor since 2005, despite the presence of a range of suitable habitats. A single male hen harrier and a ringtail were seen during April and early May separately, but no breeding behaviours were observed, and numerous interactions were recorded with buzzards locally which seem to be the dominant raptor observed in the region due to the loss of hen harrier preferred habitats and the predominance of mature conifer plantations preferred by the buzzard.

Similarly, no breeding hen harrier were observed in the Curlew Mountains region (Co. Roscommon) during any of the national surveys to date, despite it holding a range of suitable habitats. A foraging and hunting male was seen in June 2022, but no breeding behaviours were observed. Surveyors reported that recreational and tourism walking activities were a cause of likely disturbance to hen harrier in this region, particularly where users stray from trails across breeding habitats. Surveyors have also reported that over-grazing (by sheep and deer) is negatively influencing the sward height of heather across potential breeding habitats, making large areas less suitable for breeding hen harrier.

The breeding population of Devilsbit, Slievefelim, Silvermines, King Hill complex (Co. Tipperary) was marginally higher in 2022 than the first national survey in 1998-2000, but it has declined by one third since 2015. There are a wide range of threats and pressures recorded in this region by surveyors, associated particularly with agricultural activity, forestry management, wind energy, tracks and paths and recreational activities, including humans on foot, horses, scramblers and other off-road vehicles. Self-seeded conifers have been reported as a likely significant factor negatively affecting the suitability of heather moorland for hen harrier across this set of mountain ranges.

Only small numbers of breeding hen harrier have ever been recorded in east Cork and Co. Waterford. In 2022, there was a maximum of one pair recorded (same as 2015 and 2010). This region may have potential to hold more breeding hen harrier as some extensive areas of suitable breeding habitat were recorded by surveyors but also some extensive mature forest plantations any of which were occupied by breeding buzzard.

The Galtys (Co. Cork and Tipperary) population has declined by around one third since 2015 and by more than two thirds since a peak in 2010 (six breeding pairs). Surveyors reported that habitat suitability in the region was poor and highly fragmented, and dominated by mature, thicket stage (closed canopy) conifer forest. There were also reports by surveyors of agricultural improvement and over-grazing of both grassland and heather moorland, with low prey abundances.

The Inishowen Peninsula (Co. Donegal) continues to contain some suitable habitat and winter roosting birds were frequently recorded. There were no breeding hen harriers recorded here in the 2022 survey. In the past, this region held small numbers of breeding hen harrier and surveyors are optimistic that breeding hen harrier could occur in this area if suitable habitat is protected and maintained (D. Moloney, local observer, pers. comm.).

County Kildare has not held records for any of the national breeding hen harrier surveys, although a number of sites in the county support wintering hen harrier, particularly around some of the lowland raised bogs. There seems limited likelihood of a large range expansion for the county, but it may hold important overwintering reservoirs for the species.

Within the Knockmealdowns, Kilworth, and Comeraghs (Co. Cork & Co. Waterford), a region which has been a stronghold for the species, numbers have fallen by 70% since 2015. Surveyors have identified pressures from extensive sheep-grazing of moorlands and the occurrence of intra-specific interactions of hen harrier with tree-nesting raven and buzzard. Both species are associated with mature conifer plantations. Across this region, and

elsewhere, the habitat composition is dominated by mature conifer woodlands, which favour nesting buzzard. Such habitat changes have resulted in the displacement of hen harrier, rather than any effect of the buzzard per se. Human disturbance, walking trails and wide-ranging fly-tipping have also been recorded for the region. Habitat factors such as the presence of invasive species, *e.g.* rhododendron, heather burning, and maturation of conifer plantations are likely contributing to a reduction in suitability of habitat for breeding hen harrier across this region.

The population of the Leitrim, Slieve Rushen, Cavan complex (Co. Leitrim, Co. Cavan) has increased from all surveys until 2015, to a maximum of 15 breeding hen harrier territories. However, by 2022, a decline of 27% from this peak has been observed. Nearly one third of pairs in this region appear to have been lost, although a few novel pairs were also located during 2022 around Cuilcagh Mountain, which held the majority, six of eight pairs identified. The remaining two pairs were recorded in Northern Ireland, on the Fermanagh side of the mountain. The wide range of pressures and threats for hen harrier reported within parts of this region ranged from recreation (including pressure from quad-biking), wind energy development, over-grazing, agricultural disturbance, invasive species (*i.e.* self-seeded conifers, rhododendron), forestry management and afforestation, loss of scrub and natural habitats, fragmentation, wildfires and burning and erosion of peatlands. A review of hen harrier populations in this region over a multi-year study (GET, 2022a) has provided a detailed assessment of pressures, threats, and opportunities within the Cuilcagh Mountain part of the Leitrim, Slieve Rushen, Cavan complex for conservation of the species.

The counties of Longford and Roscommon have only occasionally held one pair combined in the past. None were recorded during the 2022 survey, although some various suitable habitats were evident, and the hen harrier is often recorded in this region in the over-winter period. Small numbers of breeding curlew and red grouse are present. While future survey effort in this region may encounter a small number of novel pairs of hen harrier, the 2022 surveyors reported that forestry, fly-tipping, human and vehicle disturbance, and turf cutting are factors which likely compromise the suitability of the region for breeding hen harrier.

The Nagles (Co. Cork) population has been lost, a region that formerly held up to 11 pairs of hen harrier. Surveyors covered all of the known breeding sites and any additional suitable habitat, which is now very scarce. The hen harrier is now extinct as a breeding bird in the Nagles and probably has been for the past two to three years (T. Nagle, local surveyor, pers. comm.). The last known breeding attempts were in 2019 and the last confirmed breeding that can be established was in 2017 or possibly 2018 (anecdotal information). Surveyors reported that the condition of supporting habitat for hen harrier has deteriorated significantly over the past 10 years and vast tracts of the Nagles are now covered in mature forest, and former large areas of rough grassland around the perimeter have since been reclaimed for dairy farming. Recreational disturbance caused by scramblers, quad bikes, and walkers with dogs (particularly at weekends) are also problematic. The buzzard population has increased dramatically throughout the hen harrier range in Ireland, including the Nagles. The interactions between these two raptor species can result in mobbing behaviours by the hen harrier, and its associated energetic costs defending territories (M. Ruddock, personal observation). The increase in the buzzard population and range, both in the Nagles and nationally, has been supported by the changed afforested landscape, within which the hen harrier previously occurred, and the mature forest stages more suitable for buzzard than hen harrier. Thus, habitat change due to forest maturation in areas juxta-positioned within the former breeding range of hen harriers, is driving an increase in observed buzzard-hen harrier interactions. Nationally and locally, buzzard numbers were lower during the 2015 survey and the Nagles has since reached close to optimum conditions in terms of habitat suitability for buzzard, whereas former hen harrier breeding areas have been planted and/or are now matured forest and largely unusable for hen harrier. Surveyors report that harrier winter roosts have declined to zero occupancy in the last three to four years and that both proposed and consented wind energy developments in the region may further reduce suitability of habitat for hen harrier. Overall, these associated land use pressures may stymie attempts at future re-colonisation if the amount of available and useable forest habitat for hen harrier improves over time (T. Nagle, local surveyor, pers. comm.).

The breeding population of hen harrier in north and west Co. Clare has declined by around one quarter since 2015 (22%) and by around 56% since the peak recorded in the 2010 survey. These declines are extensive, although some novel areas were identified just beyond this region where some pairs may have relocated since 2015. Surveyors here observed that wind turbines and associated infrastructure (including erection of electricity pylons) may be causing disturbance and displacement. Interactions with other species were also reported, primarily raven and buzzard. As previously mentioned, these two species are present largely due to the abundance of mature conifer plantations. Other pressures include recreational users (including dog walkers), reported near to existing and previous nest sites causing direct disturbance and a wide extent of unsuitable habitat. Some pairs of breeding curlew were recorded, which was a positive for the region.

There has been no record of breeding hen harrier in the north-west region or in the Ox Mountains, Co. Sligo over the last three surveys. The Ox Mountains held small numbers of breeding hen harrier (<3 pairs) up to and including the 2005 national survey, but none have been recorded subsequently. These areas are heavily overgrazed by sheep across extensive parts of the heather moorland and blanket bogs but are considered by species experts to have high suitability for potential habitat restoration and could be optimised for breeding hen harrier in the future.

The Slieve Aughties region (Co. Galway and Co. Clare), which is larger than the Slieve Aughty Mountains SPA, has had its population decline by around two thirds since 2015 and now holds fewer than six pairs of breeding hen harrier. The extent of declines here since previous surveys is severe, with an 82% decline when compared to the peak population recorded in 2005 (27 breeding pairs). The extent of losses of breeding hen harrier in the region are widespread and substantial in the national context. The range of pressures and threats recorded by surveyors include a predominance of coniferous forest plantation and the associated forest and plantation management and use, forest clearance (clear-cutting, removal of all trees) and wind energy developments and associated utility and service lines (*e.g.* power-lines, pipelines). There was also a spectrum of grazing levels across the region, from intensive grazing by sheep and deer to non-intensive grazing. In some areas, a notable abandonment of pastoral systems, and lack of grazing provided excellent suitable habitat but was countered by totally unsuitable habitat in other areas. The extent of turf cutting, including both hand-cutting of peat and mechanical removal of peat, is widespread, across large areas of supporting peatland habitat, and the associated impact includes human and machinery disturbance at key temporal periods during the breeding season. Various recreational activities including paths, tracks, cycling tracks, outdoor sports and leisure activities, recreational activities such as walking, horse-riding and various off-road vehicles were also recorded by surveyors. In addition, extensive and uncontrolled burning (*e.g.* widespread unmanaged and/or malicious burning) was reported by surveyors across the region which is likely contributing to the loss and/or poor condition of supporting habitats for both breeding hen harrier and their prey.

The Slieve Beagh region, which is similar to the area covered by the SPA boundary (see Section 6.4) has had a similar number of breeding hen harrier since national surveys commenced and there have been no nett changes since previous surveys in 2015. There was a single year where numbers peaked (six) in 2010 and numbers are now 50% lower (three pairs) than that peak. There is potential capacity at this cross-border complex to hold greater numbers of pairs, but it is also known that pairs can move across the border to Northern Ireland in some years. As a result, there is a flux in total population numbers between years. A wide range of pressures in this region were reported by surveyors and include extensive disturbance and displacement associated with industrial scale turf extraction that is occurring extensively across this mountain range. The known loss of habitat for hen harrier due to this activity appears sizeable. There have been recent habitat restoration activities within Northern Ireland, at the border region (CANN, 2022) with red grouse, snipe and breeding curlew recorded. A review of hen harrier in this region over a multi-year study (GET, 2022b) has provided a detailed assessment of pressures, threats, and opportunities within the Slieve Beagh Mountain complex for conservation of the species. This includes tackling the wide range of pressures

and threats within parts of this region ranging from recreation (*e.g.* quad biking), over-grazing (by cattle, sheep and deer), agricultural disturbance, invasive species (self-seeded conifers, rhododendron), forestry management, loss of scrub and natural habitats, fragmentation, fencing, turf cutting, wildfires and burning, and erosion of peatlands.

The Slieve Bernagh to Keeper Hill (Co. Limerick, Co. Tipperary) population has declined since 2015, by around 43%, a notable change from a recorded increase between 2010 and 2015. At present, the population is slightly higher than recorded numbers in 2005 and 2010. Available habitat has been reported by surveyors to be increasingly modified due to agricultural activity in this area with the loss of scrub and both foraging and nesting habitats for hen harrier. This region, which includes the boundary edge of Slieve Felims to Silvermines Mountains SPA, could be important in terms of wider recovery and/or population management within the SPA itself (see Section 5.4)

The Slieve Blooms region, similarly bounded by the SPA (see Section 6.4) has decreased by one quarter since the 2015 national survey. This region has been long dominated by high quality and extensive tracts of open heather moorland habitats which supported relatively high numbers of breeding hen harrier previously, although many forested habitats are found across the lower slopes and valleys of this mountain range. Forest management activities including forest and plantation management and use; forest replanting (*i.e.* replanting on forest ground after clear-cutting) and forest clearance (clear-cutting, removal of all trees) are large determinants of hen harrier distribution and abundance. Alongside forestry management activities, the 2022 survey recorded high levels of recreational usage in this region associated with existing walking paths, tracks, cycling tracks, created through a combination of outdoor sports and leisure activities and other recreational activities including walking, horse-riding and both non-motorised vehicles and motorised vehicles and off-road motorised driving (scramblers, quads, cars). These recreational activities are regarded as causing high levels of human-related disturbance and/or displacement to hen harriers. Improved access across the region is being generated through path creation, including cutting trails across areas of deep heather and ultimately these disturb and compromise high-quality breeding habitats. In many of the farmed habitats within this region, surveyors reported agricultural intensification and grazing (under- and over-) and agricultural fertilisation as affecting hen harrier and altering their distribution and abundance. The mechanical removal of peat and installation of utility and service lines (*e.g.* power-lines, pipelines) are also leading to increased human activity and further fragmentation and loss of habitats in the region and is considered by surveyors to be affecting breeding hen harrier locally.

The Stack's, Glanarudderies, Knockanefune, Mullaghareirks, north of Abbeyfeale region is an extensive area of land, which includes the Stacks complex SPA, and historically has held the largest proportion of the national population. This region's population has declined by around 10% since the previous national survey in 2015, and by 38% since the population peaked in 1998-2000 (45 pairs) and 2005 (45 pairs). Whilst this complex retains the largest proportion of the national population of the hen harrier in Ireland, more than a third of this former stronghold for the species has been lost in the last 20 to 25 years. Surveyors in the region in 2022 reported that afforestation (*i.e.* forest planting on open ground, an increase in forest area, planting such as on grassland, heathland) and forest and plantation management and use and reafforestation, or forest replanting (*i.e.* replanting on forest ground after clear-cutting) are considered substantial factors affecting the distribution and abundance of hen harrier in this region. There are also large areas of supporting habitats, which are subject to intensive grazing and uncontrolled burning (*e.g.* widespread unmanaged or deliberate burning) across grassland and heather moorland and blanket bog habitats. These activities are known to be particularly damaging to the prey abundance and suitability of habitats for the hen harrier (NPWS, 2015b). Similarly, field observations report that both hand-cutting and mechanical removal of peat are sources of disturbance and damage to hen harrier and their breeding habitats. Often, such activities co-occur with both extant and prospective wind energy development sites and addressing these requires the implementation of appropriate management actions for the region (NPWS, 2017; Mee, 2019).

West Cork has only ever held minimal numbers of hen harrier: a maximum of one pair in the previous survey (2015), with none recorded in 2022. This area was reported by surveyors to have poor condition of suitable habitats, indicative in some cases of past fires leading to loss of suitable heather moorland habitats. High levels of buzzard activity were recorded in some areas which is due to a preponderance of mature conifer habitats occupied by that species, and which are typically actively avoided by hen harriers.

Similarly, west Kerry has not during the time-frame of any of the national surveys 1998/2001 – 2022 held any breeding hen harrier, but one novel pair was recorded during the 2022 survey. Successful breeding of small numbers of pairs has been recorded in this area in recent years, including broods of four chicks fledged, and if appropriate conservation actions were implemented to support the birds, then this region could increase the range of the species with a small number of pairs within suitable habitat. Small scale localised management applied across Ireland at regional levels could result in national numbers increasing. Associated disturbance of potential breeding pairs due to clear-felling, has been anecdotally reported in west Kerry.

County Wexford previously supported up to two breeding pairs of hen harrier, but none have been recorded in 2022, nor in recent years (T. Murray, NPWS, pers. comm.). Surveyors reported that agricultural improvement and reclamation of formerly hen harrier-occupied land parcels has occurred in recent years, and the suitability of past breeding sites has been significantly compromised.

The Wicklow Mountains holds large areas of extensive heather moorland and blanket bog habitats although extensive over-grazing (by sheep and deer) and a number of extensive fires have been recorded in the region in recent years, including during 2022. This region historically held a population (7–10 pairs) of hen harrier in the 1960s (Watson, 1977) but since national surveys began in 1998/2000, there have been no breeding territories recorded here, despite apparently suitable and available habitats. A single female was seen passing through in the summer season of 2022, but no breeding behaviours, or indications of such, were observed.

Other areas, not located within these aforementioned defined mountain ranges (as per Norriss *et al.*, 2002; see Barton *et al.,* 2006 for map of regions), held a small number of pairs, including in squares that have not previously held records of breeding hen harrier. For this grouping, there were five confirmed pairs and one possible pair recorded in 2022 which is a 50% increase since the 2015 survey. These squares also held a further 23 records of harriers which were defined as ‘seen’ but exhibited no breeding behaviours; some of these were recorded outside of the breeding season and therefore considered moreso records of over-wintering birds. Surveyors reported some areas of suitable habitat and a range of pressures and threats in these areas including those related to forestry management, human disturbance, agricultural activities and recreational users (particularly off-road vehicles) (see Appendix 2 and 3 for details of activity, pressures and threats descriptions). Some areas were reported to have been re-occupied by breeding hen harrier, for example in an area where turf cutting has ceased over recent years.

4.4 Population estimates, population changes and habitat composition within SPAs

The hen harrier SPAs have been recorded to hold most of the national hen harrier population in the majority of the national breeding surveys. The 10 km squares (n = 56) that overlap the SPAs held 50 confirmed and six possible breeding territories (56 pairs) during 2022 which is 53% of the national population. Within the SPA boundaries, a smaller number of pairs occur (38-43 pairs) since the SPA boundaries do not encompass the whole 10 km squares. The rate of population decline appears to have accelerated within the SPAs. It may also be the case that some pairs persist beyond the boundary and/or some localised redistribution has occurred beyond the SPA boundaries, although the total numbers of pairs in these ‘SPA 10 km squares’ are much lower (at 56 pairs) than recorded in 2015 (total of 77 pairs). Thus, declines have

occurred both within and beyond the SPA boundaries in the SPA regions (see Section 6.3). Declines appear to have accelerated since all previous surveys, from 18% for the period 2005 to 2010; 10% for the period 2010 to 2015 to 38% for the latest comparison of 2015 to 2022. The rate of decline in the SPAs has more than tripled within these past seven years despite extensive management supports via the Department of Agriculture, Food and the Marine (or DAFM's) Green, Low-Carbon, Agri-Environment Scheme (GLAS) and the Hen Harrier locally-led, results-based programme (HHP).

During the 2022 survey, the six SPAs held around 41% of the national population (43 of 106 pairs). This is lower than the 44% of the national population held by SPAs in 2015 (Ruddock *et al.*, 2016). The SPA population decline (38% since 2015) amounts to a loss of 26 pairs across the seven-year period. The 1998/2000 and 2005 national survey data were used to inform the selection of candidate SPAs in 2007 and the total SPA population has declined by more than half since that time. The Slieve Blooms SPA had one more pair in 2022 (9) than in 2005 (8) and fewer pairs than in 1998/2000 (11) and declines, at the other five SPA sites, across this period (1998-2000 & 2005) ranged from 20% to 80% (-53%; -80%; -20%; -67% and -25% respectively; see Table 10).

It is known from annual monitoring of breeding hen harrier conducted as part of the DAFM results-based programme (HHP, 2018; 2019a; 2019b; 2020; 2021) that total numbers of pairs and productivity can vary between years. Most recently, in 2021, HHP monitoring (HHP, 2021) indicated a stabilisation of numbers of territorial pairs, ending a year-on-year decline for the SPAs from 2018 to 2020. However, the 2021 breeding season was the least productive on record, with just a third of nesting pairs in the SPA network successfully fledging a total of just 34 young (HHP, 2021). Subsequently, in 2022, the sudden decline in the total number of nesting pairs is marked (see Appendix 4). This sudden and sharp decline may be an artefact of continued poor breeding productivity and/or other constraints acting on the population, both within the SPAs and nationally, that have reached unsustainable levels and/or contributed to high levels of mortality (Murgatroyd *et al.*, 2019). It is recognised there may also be an absence of breeding due to extrinsic factors such as weather or low prey availability but the recorded sex-biased observation information, with more males seen than females across the survey data (Appendix 1), indicates a wider population problem and requires further research. Notwithstanding agricultural programmes, the other sectoral pressures such as recreation, wind energy developments, and forestry within the SPAs and nationally may also exacerbate such sudden declines as all these factors are likely operating cumulatively on the hen harrier.

The SPA populations have not stabilised since the time they were proposed as candidate SPAs, 15 years ago. The species needs strategic and long-term, objective focused management plans to improve the fortunes of the species both within and beyond the SPA sites. A Hen Harrier Threat Response Plan (HHTRP) has been in development for 11 years; and incorporates a strategic environmental assessment, appropriate assessment, and public consultation. Annual monitoring of the SPAs has shown that productivity can be high within some years (HHP, 2019b) and measures to improve breeding success must be a key focus of management and conservation of the species (Newton, 1979; Fielding *et al.,* 2011; Fernandez-Bellon 2020).

The Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPA population has declined by 53% since 2005. This SPA supports many scrub nesting hen harrier, with heather nest sites rarely recorded and second rotation sites recorded less frequently, due perhaps to maturation of forest estates within this site and a widespread absence of heather moorland (M. Ruddock and F. Connolly, *pers. obs*.). The total numbers for this site are around 25% lower than in 2015 and have steeply declined (38%) since 2021 (34 pairs; HHP, 2021). The SPA is located across 18 different 10 km squares and 12 (67%) of these 10 km held at least one breeding pair. Spatially, the hen harrier is widespread in the SPA but occurs at low densities for the most part, except for one area where at least six pairs occurred within one 10 km square. As noted, (Section 5.4), a range of pressures and threats have been recorded in this SPA and wider region but most frequently occurring issues recorded by surveyors were the loss of habitat due to afforestation, disturbance by forestry management activities and the

loss of scrub habitat through agricultural activity, predation and displacement by recreational activities and wind energy development.

The Mullaghanish to Musheramore Mountains SPA has historically been one of the smaller populations within the SPA network, with a maximum of five pairs recorded in 2005. It has declined successively across each of the subsequent national surveys, with the 2022 estimate on par with 2015 (one pair). Since that 2005 peak of five pairs, there has been an 80% decline in the population of hen harrier. Recent monitoring between 2017 and 2021 revealed a consistent population of only 1-2 pairs, a single year (2020) when the population peaked at five pairs (HHP, 2020) and a decline again in 2021 to three pairs (HHP, 2021). The SPA extends across six 10 km squares, but only a single 10 km contained breeding hen harrier in 2022, with an additional pair recorded beyond the SPA within a second 10 km square. The range of the species at this site has substantially reduced, with hen harrier now occupying only one part of their former range. Surveyors reported a high dependency of harriers on scrub habitats within this SPA. However, the area is frequently subjected to agricultural intensification and activities such as the removal of scrub habitats and over-grazing, are negatively affecting the suitability of breeding and foraging habitats across the SPA resulting in direct and indirect loss of habitats.

The Slievefelim to Silvermines Mountains SPA was one of only two sites that recorded an increase in the hen harrier population during the period 2005 to 2010 and to 2015, with a doubling of the population between 2005 and 2015 from 5 pairs to 10 pairs although a slightly higher number were recorded in 1998-2000 (8 pairs). In 2022, the population was 60% lower than 2015, and 43% lower than in 2021. Overall, it is lower than previous yearly totals for the period 2017 to 2021 which fluctuated between six and nine pairs (HHP, 2018; 2019a; 2019b; 2020; 2021) (HHP, 2021). The SPA extends over nine 10 km squares and only 44% (four) of these squares held breeding hen harrier; these were located primarily in the southern portion of the site. Surveyors observed a significant level of disturbance at this site due to walkers and off-road (scrambler) bikes and forestry activity. The moorland and other suitable hen harrier habitats are also observed to be affected by invasive self-seeded conifers and, increasingly, by rhododendron.

The Slieve Bloom Mountains has generally maintained a stable or slightly increased population since the first national surveys (1998/00, 2005) (8-11 pairs). It peaked during the 2015 national survey (12-13 pairs) but has by 2022, apparently declined to around 2010 levels (8-9 pairs). Annual monitoring for the SPA (HHP, 2021) recorded a peak in 2017 (10-14 pairs; HHP, 2018) and the population declined thereafter to around 10-11 territorial pairs annually, between 2018 and 2021. Variable numbers of young fledged across years, including recorded zero productivity in 2021. The decline in 2022 from more recent years (HHP 2017-2021) is marginal and changes since 2015 demonstrate an overall 12% increase, indicating relative stability in the total number of pairs. All of the Slieve Bloom breeding pairs were located within heather habitats and none in afforested habitats. Surveyors reported that the adjacent coniferous forest plantations are a source of potential predation risk (see also Sheridan *et al.*, 2020) and that extensive and invasive self-seeded conifers are compromising the remaining available heather moorland and other supporting habitats, preferred by the hen harrier. The preservation and protection of areas of deep heather from cutting, or flailing management and heather burning is critical, and any such damaging activities of these supporting habitat features should be prevented, with appropriate measures taken with respect to any breeches of conditionality and/or the wildlife legislation. Recreational walkers should be targeted for awareness raising to discourage and prevent the creation of new, and extension of existing, paths and routes through nesting habitats. Collectively, surveyors in the area consider that there is a lack of spatial and temporal planning of disturbing activities, particularly forestry management, recreation and recreational events that are causing disturbance and displacement to hen harrier in the area and requires collective conservation action (Gallagher & Lauder, 2016).

The population of the Slieve Aughty Mountains has declined extensively and successively across all national surveys and by two thirds since 2005, with just five pairs recorded in 2022, a loss of more than 20 pairs in the intervening 17-year period. Annual surveys of the SPAs

(HHP, 2018; 2019a; b; 2020; 2021) found continued gradual declines between 2017 (12 pairs); 2018 (9 pairs); 2019 (6 pairs); 2020 (6 pairs) and 2021 (7 pairs). This SPA has declined to the point where, largely due to habitat fragmentation, it may be ecologically compromised (*e.g.* Jones *et al*., 2009; Fernández-Bellon *et al*., 2021) with only small numbers of young produced each year. A former stronghold for the species, it held the second highest numbers of pairs nationally in 1998-01; 2005; 2010 and 2015. There is a probability, given the magnitude of declines recorded from 2017 – 2022, that at the current rate of decline that there will be no successfully breeding pairs of hen harrier in the SPA within five years. The surveyors in the region reported that habitat-mediated effects, dominated by non-native conifer plantations, are key determinants of hen harrier population levels and breeding success and ultimately population viability in this region. That is, the extent and configuration of conifer plantations across the site, and the maturation of the forest estate in recent years, has resulted in a lack of availability of breeding habitats (including loss of open habitats through afforestation and the prevalence of thicket stage forest, which is unsuitable for nesting hen harrier). Other effects associated with dominant forest cover include elevated predation risk, and associated edge effects and resultant poor productivity (Irwin *et al*., 2012). Forestry management actions and recreational projects and other potentially disturbing activities exhibit a lack of strategic planning occurring in the region resulting in excessive levels of disturbance and displacement of hen harrier during the breeding season and a site-specific management plan is much needed for the Slieve Aughty Mountains.

Slieve Beagh is a relatively small SPA, but the area has regularly held hen harrier for many decades. This SPA is part of a wider cross-border mountain range where pairs regular switch jurisdiction between years as foraging ranges of pairs are contiguous, in both directions, across the border with Northern Ireland. The highest total of six pairs in 2010 (Ruddock *et al.*, 2012) has since declined by half to three pairs in 2022. Earlier surveys recorded three pairs (1998-2000) and four pairs (2005). The HHP EIP (2021) review of annual surveys (2017-2021) shows that there were typically three to four pairs in most years indicating that the site was relatively stable with a consistent population. In one year (2018), there was a peak (six pairs) which then decreased the following year again. The tendency of the population to increase (and decrease) precipitously gives cause for both concern and optimism about the capacity for rapid changes within populations. The population fluctuations in this region are more complex due to the dynamic spatial changes across the Northern Ireland border within and between years (GET, 2022b) and it may be ecologically more coherent to consider both jurisdictions as a collective population when reporting. Surveyors in this region cite the extensive and damaging occurrence of turf cutting, which happens primarily in Ireland, not Northern Ireland, through various mechanical means as the most significant land management activity affecting hen harrier and their prey. The widespread occurrence of turf extraction across the mountain and its temporal nature (typically from early May – August), results in seasonal sterilisation of hen harrier foraging habitats, combined with direct breeding season disturbance and displacement of hen harrier. Human activities, particularly rally cars / events, walking, unleashed and unsupervised dogs, and agricultural activity (notably fencing) including cross-border actions are considered to be creating high levels of displacement and disturbance to a range of species including red grouse, snipe, curlew, and hen harrier. Wildfires and deliberate burning are a feature at this locality, year on year, causing widespread loss of habitat, most often in the spring when such fires destroy large numbers of nests including hen harrier and other upland ground-nesting bird species (red grouse, meadow pipit and skylark) (see also GET, 2022b). These issues have persisted (see RSPB, 2011) in the region, and in many cases, have intensified over time (GET, 2022b). Some progress into the management of specific issues have been made *e.g.* PauCosta, 2022 (Wildfire Management Plan) and there are a mosaic of stakeholder needs and aspirations locally (Sliabh Beagh Master Plan, 2017). Many of the aspirations, *e.g.* tourism and hen harrier, are interlinked, and are not mutually exclusive and may be competing.

4.5 Breeding outcomes and habitats utilised

Breeding performance and breeding success of pairs is known to vary between years (see Ruddock *et al.,* 2012; 2016) and is influenced by intrinsic (*e.g.* breeding age; experience; survival) and extrinsic (*e.g.* weather; disturbance; prey availability) factors (Paviour, 2013). Nest initiation rates observed in this survey were relatively high in territorial pairs of hen harrier (89%) which is greater than both 2010 (66%) and 2015 (87%) (Ruddock *et al.,* 2012; 2015). Overall, though the observed hatching success (76%) of confirmed pairs in 2022 provides some basis for optimism that the capacity for producing young exists within the Irish hen harrier population. This is countered by the subsequent fledging rates which are much lower (44%). The latter (*i.e.* fledging rates) is akin to the rates observed in 2015 (45%; Ruddock *et al.*, 2016); 2010 (39%; Ruddock *et al.,* 2012) and 2005 (44%; Barton *et al.*, 2006) indicating ongoing poor final breeding performance at the fledging stage and outputs. The inclusion of "possible" pairs of hen harrier that have also failed then the overall failure rates of 60% is comparable to figures for 2015 (62%) and remains higher than 2010 (51%) (Ruddock *et al.*, 2016; 2012 respectively).

The high failure rates after hatching and prior to fledging (40%) indicate that there is capacity for recovery of the Irish hen harrier. If the rate of fledging can be increased, through targeted management particularly in the late nestling stages when high levels of failure appear to be occurring. These parameters can be highly dependent on habitat optimisation (Newton, 1979) and improvement of year-on-year success and consistency within prey-rich habitats (Tapia & Zuberogoitia, 2018) that can be enhanced by:

- habitat, species- and site-specific management (Fernandez-Bellon *et al.*, 2021)
- potentially by supplemental feeding (Redpath *et al.*, 1999; 2001; Amar & Redpath, 2002) and/or
- nest protection measures such as predator management (McMillan, 2014)
- regulation and management of activities within protective buffer zones (Ruddock & Whitfield, 2007).

The overall productivity rates recorded during 2022 were 0.9 young fledged per confirmed pair, 1.0 young per nesting pair and 0.7 young per breeding pair. The number of young per confirmed pairs is similar to 2015 (Ruddock *et al.*, 2016; 0.94) and higher than 2010 (Ruddock *et al.,* 2012; 0.81). Recently, NPWS (2022) defined productivity targets for the site-specific conservation objectives based on 1.0-1.4 young (per confirmed breeding pair) for SPAs within Ireland. The observed rates recorded during the survey are 10% to 36% lower than the productivity targets set by NPWS (2022) for confirmed pairs and are 38% below the 1.45 young per breeding pair target of O'Donoghue, (2010) used to define the HHP threshold targets (HHP, 2019; 2020; 2021). The observed productivity rates also remain below that of other populations (Watson, 1977, Green & Etheridge, 1999; Redpath *et al.*, 2002a; 2002b; Barton *et al.,* 2006; Amar *et al.,* 2007; Irwin *et al.,* 2008; Scott & Clarke, 2008; Whitfield *et al.*, 2008; Whitfield & Fielding, 2009; O'Donoghue, 2010; Fielding *et al.,* 2011; Irwin *et al.,* 2012; O'Donoghue, 2021). This continued poor performance, compounded by poor juvenile survival rates (McCarthy, 2022), exacerbates the population decline (Ruddock *et al.*, 2016).

For a population to be considered stable, the net losses through mortality and dispersal (emigration) comparative to gains through productivity, juvenile survival, and dispersal (immigration) must be equivalent. The average number of young that each pair must produce annually, given the level of mortality and displacement, to maintain a steady population is known as the 'recruitment standard' (Newton, 1979). For a population to be increasing and considered to be at 'favourable status', it needs to be capable of maintenance and/or expansion where population gains (inputs) are greater than losses (outputs) of birds, and without dependency on recruitment from other populations *i.e.* immigration.

Various productivity thresholds for population stability and/or expansion and to achieve favourable conservation status have been set out for different sub-populations including 1.1-

1.2 young (Newton, 1979); 1.0 young (per occupied site; Fielding *et al.,* 2011); 1.2 young (per breeding site; Fielding *et al.,* 2011); 1.2 young (per breeding attempt; Whitfield & Fielding, 2009). The latter study (Whitfield & Fielding, 2009; Whitfield *et al.,* 2008) was of an increasing population and productivity was 1.42 young (per breeding attempt) and Fielding *et al.,* (2011) also recommends a target of a minimum of 1.2 young per breeding attempt is required for stability in the medium to long-term.

For the 2022 survey, the number of young (per confirmed breeding pair) observed was 1.0 young outside the SPAs (wider countryside) and 0.82 young inside the SPAs. These estimates are sub-threshold or below the lower limit of the targets set out by NPWS (2022), albeit marginally higher than national estimates for 2015 (0.94 young) and 2010 (0.81 young) surveys. Thus, there is a shortfall in the mean number of young being fledged in Ireland within or outside the designated sites and that needed to maintain or increase the population. Current productivity rates are insufficient to increase the population which is, in turn, likely to be incompatible with either maintaining population stability or indeed population recovery. The population productivity threshold could be achieved by either achieving a relatively low number of young fledged per successful nest combined with a high proportion of nests being successful, or by reaching higher productivity per successful nest but with relatively few nests fledging any young. The target for conservation objectives (1.0-1.4 fledged young per confirmed pair), may be lower than required for the immediate reversal of the population declines in the short-term and to restore a self-sustaining population of hen harrier in Ireland.

Following the methods of Ruddock *et al.*, (2012; 2016), a population model for each SPA and the wider countryside was constructed using breeding parameters from 2022 (see Appendix 5). This model assumed age-specific annual survival estimates (Etheridge *et al.,* 1997), that the populations were closed and in the absence of any existing estimate of non-breeders in Ireland. These survival parameters were utilised for the purposes of comparability with previous surveys. Although specific estimates for adult survival of harriers are not known, there are Irish estimates of juvenile survival (O'Donoghue, 2010; McCarthy, 2022) which are much lower than Etheridge *et al*., (1997). The model predicts a national deficit of 19.9 hen harrier from 2022 to 2023 as both the SPA network and wider had no surplus (-7.9 & -12.1 respectively). Using the juvenile survival estimates in Ireland, which are lower than those reported for Scotland, the deficit may be much higher -28.3 (based on 0.25 of McCarthy, 2022) and -35.1 (based on 0.16 of O'Donoghue, 2010).

There was no surplus of hen harrier recorded either within or outside any of the SPAs, and although deficits were apparently lower from initial models than previous estimates of deficits (Ruddock *et al.,* 2012; 2016), this may be an artefact of a much-decreased population since previous surveys. Year to year variability in productivity for hen harrier in Ireland is established (see review in NPWS, 2022), but the current scenario appears to be one of ongoing year-on-year deficits, resulting in an ever-decreasing national and SPA population. The reversal of population declines requires significant efforts to improve breeding success and numbers of fledged young in order to produce an annual surplus both within and beyond designated sites. The populations within and outside the SPA network cannot be considered favourable and may continue to operate as population sinks that are dependent on recruitment from areas outside of Ireland. Further consideration of the multi-year datasets and breeding parameters (from all national surveys, research studies and HHP 2017–2022) for the conservation objectives, as detailed in NPWS (2022), will improve estimates of the population model parameters (see Fielding *et al.,* 2011; New *et al.,* 2011; Morrison *et al.,* 2016b) for Ireland's hen harrier SPAs.

Surveyors have recorded that the wider loss and degradation of formerly-suitable breeding and foraging habitats, particularly through agricultural improvement, removal of scrub and heather; afforestation and intensification of land management often associated with wind energy development are determinants of hen harrier occurrence and/or abundance. The quality and quantity of prey species are also likely to be significantly affected by these factors (Fernandez-Bellon *et al.,* 2019). In addition to the direct effects of land management activities on nesting failure, a range of foraging and nesting habitats have been lost through fires, afforestation, and

agricultural reclamation, both during the 2022 survey year and since the previous national survey (2015), as demonstrated by the increased numbers of unsuitable survey squares and habitat within survey squares. These field-observations are supported by the wider research (Wilson *et al.,* 2016; NPWS; 2021; Fernandez-Bellon *et al.,* 2021) and identified within the draft threat response plan (NPWS, 2021) which will require cohesive and collective will and action to restore the hen harrier breeding population.

Surveyors have also recorded various suspected reasons for breeding failure during 2022 and these were largely related to anthropogenic factors and/or predation. Predation, in particular by foxes, has been shown to be an important cause of hen harrier breeding failure in some areas of Ireland and the UK (Whitfield & Fielding, 2009; O'Donoghue, 2012; Baines & Richardson, 2013; McMillan, 2014). Whilst likely to be highly site specific, in a review of fox predation at hen harrier nests on the Isle of Skye, Scotland, McMillan (2014) states that, in areas not managed for red grouse, high failure rates at the chick stage may indicate a problem of fox predation. The general view amongst raptor surveyors, including during the 2022 survey, is that most fox intrusions occur when broods are at the later stage of development (Rooney & Ruddock, 2021; F. Connolly, *pers. obs.)*. At least eight of the SPA nest sites were recorded to reach late nestling stage. Some nests were observed to be within days of fledging young *e.g.* jumping to adults for food from nest site, and yet subsequently failed. Sudden failures observed at this late stage of the nestling stage are typically due to predation (McMillan, 2014) and predation appears to remain a key cause of nest failure, including in the SPAs.

Forested areas, and the associated habitat provision and optimisation for other predatory species *e.g.* pine martens, buzzards and foxes, may cause direct effects whereby forested habitat, particularly as it matures, is displacing hen harrier while providing suitable habitat instead for those other species *e.g.* buzzards nesting in mature commercial plantation woodlands which are not used by hen harrier. Furthermore, such change is contributing to increased interactions *e.g.* mobbing and chasing between the two species can occur at the interface/edge of these habitats. Forest and forest edge can also lead to indirect predation effects arising (Sheridan *et al.,* 2020).

Forest management is identified as a primary threat to breeding hen harrier (Bonsu *et al.,* 2019; Fernandez-Bellon *et al.,* 2021) and is having a direct disturbance effect both within and outside of the SPAs. This is causing direct disturbance and displacement both in the early breeding season (in February and March) during territorial settlement or prospecting phases and during the rest of the breeding season and nesting cycle. Machinery usage, most frequently through agricultural and turf cutting activities, is causing extensive loss of habitat year on year and also direct disturbance to harriers during the breeding season. Similarly, the inappropriate timing and usage of off-road motorbikes, along with recreational users, including dog walkers, would benefit from extensive engagement to reduce negative effects on hen harrier and their habitats.

Observers report that these various activities above, occurring within forested areas, are resulting in the displacement of 'territorial' birds, prevention of nesting, as well as direct losses of nests due to direct disturbance to nesting pairs including nest destruction. The timing and occurrence of highly disturbing or destructive activities during the breeding season requires remediation and an increased level of awareness and enforcement amongst stakeholders. Although there are sometimes competing temporal or seasonal management needs for some activities, *e.g.* good weather for hiking events, winter / summer timings of activities or sports, related aquatic interests and water quality including other conservation priorities like fresh-water pearl mussel, within forested habitats with the current low levels of breeding success observed, many of these pressures may be avoidable and preventable. If these were reversed or mitigated, it could help support higher levels of breeding success to the Irish hen harrier population. This requires the implementation of increased spatial and temporal prescriptive and adaptive measures (Currie & Elliot, 1997; Ruddock & Whitfield, 2007) and stakeholder cooperation and measures to avoid and prevent disturbance and displacement.

Natural and semi-natural habitats are preferred by hen harrier (Watson, 1977) but increasingly these are being affected by habitat changes, fragmentation, and loss; these are cited as key

pressures acting on the species (Fernandez-Bellon *et al.,* 2021). Suitable, heather habitats (>40 cm; Redpath *et al.,* 1999) have become scarce within the uplands of Ireland, with restricted availability and/or highly fragmented occurrence. Their loss is frequently compounded by afforestation; over-grazing; burning (associated with provision of grazing for livestock) and intentional removal of habitat which are principally driven by agricultural improvements and the eligibility criteria within agri-environment subsidy frameworks. This has been recognised across sectors by members of the Joint Consultative Committee for the Threat Response Plan (*e.g.* IFA and eNGOs in DHLGH, 2024). There has been some progress with the recognition of scrub eligibility within agricultural subsidies (DAFM ACRES, 2023), and the further expansion of this support for biodiversity, and hen harrier, will benefit both species and farm communities. The inclusion of heather, in all its growth forms, as a beneficial feature within the eligibility framework will alleviate significant pressures on hen harrier preferred habitats in Ireland.

Scrub was the dominant habitat recorded, for nesting, within the network of habitats utilised by the hen harrier during the breeding surveys in 2022. The wooded habitat types also demonstrated similar breeding success rates 41% (second rotation) and 42% (scrub) whereas heather-dominated habitats showed a marginally higher rate of breeding success (48%). Scrub is a highly valuable habitat and appears to be recorded more frequently within the hen harrier breeding sites, both inside and outside the SPAs in this survey. Perhaps this outcome may be due to losses of heather habitats and the wider maturation of pre-thicket forest habitats within the hen harrier range. The increased prevalence of scrub nesting behaviour, in the absence of alternative habitats, has precipitated the active selection of these important scrub habitats, particularly where undisturbed. Further research on suitability and availability of habitats is required to establish if this habitat is being selected according to availability. Breeding success appears slightly higher in this habitat, although this may be an artefact of the higher proportional occurrence of scrub nesting pairs now in Ireland and/or this habitat may confer additional barriers to nest failure *e.g.* protection from predation and may be more impenetrable to ground predators.

4.6 Conclusions

This report presents a comprehensive series of results along with review and discussion of same. The observational data provided by surveyors have identified key pressures, and threats acting on the hen harrier locally, either singly or in combination and which may be operating at regional and/or at national scales and cumulatively contributing to the nationally observed decline. All local observations by surveyors were reviewed to consider potential sectoral opportunities and whilst different scales of interventions or management may be required locally, regionally, or nationally, any such opportunities for restoration and conservation of the hen harrier population should be developed with targeted measures and outputs at the scale they are applied. The recommendations (set out in Section 6.7) are informed by the 2022 survey results including the current population status of hen harrier in Ireland. Whilst not intending to replicate or duplicate the work being undertaken to develop the draft Hen Harrier Threat Response Plan (HHTRP), but they should inform the implementation of that Plan.

4.6.1 Status of breeding hen harrier

The 2022 survey of breeding hen harrier in Ireland has shown a continued decline in the national population, and the rate of decline has also accelerated since the previous survey in 2015. The total population of 106 breeding pairs is one third (33%) smaller than the total population of 157 breeding pairs recorded in 2015 and 38% smaller than that recorded in 2010 (172 breeding pairs). The magnitude of decline in total numbers of breeding pairs of hen harrier in Ireland is unsustainable and appears to have increased since 2015 (Ruddock *et al*., 2016). If the current trajectory continues (33% between 2015 and 2022 or approximately 5% per annum), then there will in all likelihood be less than 50 breeding pairs of hen harriers within the next 10 years. As required under the Birds Directive the species needs urgent and specific

interventions to stabilise to reverse the population declines and support population recovery of the hen harrier in Ireland across local, regional, and national scales.

The reliability of population estimates arising from national breeding surveys of hen harrier are important for assessing the status of the population and setting out conservation objectives[4]. There are potential biases that can arise from 5-year or, in this case, 7-year intervals between surveys. A comprehensive review of information is thus required including available data between national surveys. Various subset analyses, set out in the methods and results sections, have been used to provide comparable estimates of change between national survey periods for areas where coverage has been consistent throughout. Where survey effort is significantly different between surveys, this can complicate the drawing of clear conclusions (Lewis & Gould, 2000; Johnson *et al.,* 2019; Steiner *et al.*, 2022).

Based on the subset analyses described earlier in this report, there is certainty of a decline in population numbers of 36% between 2022 and 2015 and 47% between 2022 and 2010 and 14% between 2022 and 2005 and 59% between 2022 and 1998/2000. These are substantial declines and warrant urgent implementation of the HHTRP and specific conservation priority setting and the recommendation to use these subset analyses in the next BoCCI review. The timing of the next national survey is recommended to be conducted in 2025, and the 5-year interval schedule re-instated, given the critical level of the population in Ireland.

4.6.2 Pressures and threats for breeding hen harrier

Fernadez-Bellon *et al.,* (2021) summarised the range of pressures and threats across the hen harrier biogeographical range in Europe and identified key issues as drivers of hen harrier declines including:

- prey availability;
- agricultural intensification;
- shooting (*i.e.* persecution);
- deliberate nest destruction;
- predation;
- extreme weather
- afforestation;
- accidental nest destruction; and
- habitat loss.

The most frequently occurring pressures and threats (Appendix 2) highlighted by surveyors in 2022 as negative for hen harriers close to breeding / nesting sites (*i.e.* in the 500 m zone) include; forest management and use; the mechanical removal of peat; increased access (via paths, tracks, cycling tracks (includes non-paved forest roads); non-intensive grazing; wind energy production and agricultural intensification. These activities, at distances proximate or close to nesting sites (*i.e.* within 500 m) of breeding pairs, are considered to heighten risk of negative outcomes (*e.g.* reduced productivity, nest failures via abandonment or predation or nest destruction) although it is recognised that some of these factors can also have positive effects. For example, non-intensive grazing[5] is reported as a positive indicator for scrub and such low-intensity agricultural activity can help support hen harriers in some areas. Positive landscape features should be maintained and optimised, potentially by further grazing

[4] Conservation Objective – a conservation objective is the specification of the overall target for the species and/or habitat types for which a site is designated in order for it to contribute to maintaining or reaching Favourable Conservation Status. (NPWS, 2022)

[5] (*i.e.* reduced levels of grazing and/or abandonment of pastoral systems and/or sustainable grazing allowing regeneration of flora particularly scrub and heath)

reductions and retention and expansion of suitable habitats and habitat matrices which are beneficial to the hen harrier.

In the wider landscape, at the 2 km zone around territories (Appendix 3), surveyors also reported pressures and threats by frequency of occurrence. Again, those highlighted included all activities referenced in the paragraph above, as key determinants of hen harrier presence or absence and/or habitat suitability, with the exception of 'non-intensive grazing'. These activities are also listed in the draft HHTRP (NPWS, 2022) but there are limited recommendations and/or actions identified to address some of the pressures and/or threats, *e.g.* turf cutting and wildfires/illegal burning or recreation. At some sites, these activities are problematic for hen harrier *e.g.* turf-cutting at Slieve Beagh SPA (CANN 2022) or scramblers and quad bikes in the Slieve Felims (HHP, 2019). Some of these activities will need to be addressed in tandem with the wider sectoral pressures of agriculture, forestry, and wind energy identified in the draft HHTRP, as all of the aforementioned pressures which can operate singly or in combination at any one site or wider. Thus, mitigation will require holistic and specific management to reduce likely negative cumulative effects of these pressures on breeding hen harriers and their habitats.

Surveyors in 2022 identified three main sectoral pressures across breeding hen harrier sites: forestry (NPWS, 2015), wind energy development (NPWS, 2021) and agriculture (NPWS, 2015). The negative effects of activities associated with these sectors typically manifest directly on the species (*e.g.* nest destruction, disturbance, or displacement) and also indirectly on the supporting breeding and/or foraging habitats via destruction, disturbance, or displacement *i.e.* loss of habitats. Often forested habitats are sub-optimal for the hen harrier but are optimal for other species, such as buzzard or red fox, and this land-use is exacerbating losses of hen harrier from parts of the landscape due to changed habitat composition. The accommodation, protection, and proliferation of hen harrier suitable habitats within current landscapes (*i.e.* plantation forests, windfarms and agricultural) requires an interdepartmental approach to retain and restore suitable, and optimal, breeding habitats for hen harrier and prevent native habitats and vegetation *e.g.* heather and scrub and natural grasslands being diminished year-on-year.

4.6.3 Forestry

The Forest Service's (of the Department of Agriculture, Food and the Marine or FS-DAFM) Red Areas Procedure (Forest Service, 2012) aims to manage the interactions with hen harrier including through the implementation of protective buffer zones (also often referred to as 'Red Zones') where forestry-related activities are restricted in SPA areas. These restrictions are in place as of 2022 (from 1 March–15 August in a calendar year), but they are not being applied retrospectively to existing licenses *(i.e.* pre-2022, which continue to run from 1 April–15 August annually). This protocol applies within HLNAs which are within/overlap with the SPA boundaries only. Currently, no formal procedures are in place to protect hen harrier breeding sites from forest management disturbance outside the SPA network. Several incidents of forestry management activities (including harvesting and afforestation) which have led to the direct disturbance, loss, and displacement of breeding hen harriers both within and outside the SPAs have been recorded in recent years (M. Ruddock, *pers. obs.*). Minimising disturbance in the early season (particularly during March) would reduce displacement of birds in the breeding settlement period (Hardey *et al.,* 2013).

The Red Areas Procedure, which has been in place since 2012, requires a comprehensive review and update by the regulatory authority *i.e.* DAFM's Forest Service. A review should assess the efficacy of this management measure in protecting breeding hen harriers in the SPAs taking into consideration the changes over the past 10 years in the hen harrier population, forest management techniques, and understanding of hen harrier ecology since the protocol was first implemented. Such a review needs to consider the current population status of the hen harrier, at SPA and national level, the current rate of decline, ongoing effects of forestry management practices on the population as a whole and Ireland's obligations under the Birds Directive and upcoming Nature Restoration obligations. The existing Forest Service Red Areas Procedure is dependent on the comprehensiveness, accuracy, and contemporary

status of the data provided on hen harrier breeding sites so that unnecessary protective buffers are not enforced, and to ensure that any changes in the distribution of breeding pairs are captured between years.

The spatial extension of the current FS-DAFM Red-Areas Procedure is required and should identify and include all important breeding areas for hen harrier, not only inside SPAs but also in the wider countryside. Supports for the protection of hen harrier breeding habitats and breeding sites, via the spatial extension of the current procedure beyond SPAs would help to reduce the impact from forest sector activities during the breeding season and thereby further deterioration of the national hen harrier population and its habitats. This review and a strategic consideration of the spatial and temporal sensitivities of the species and increased annual data collection would allow improved standardised procedures for planning consents and forestry managers. Annual hen harrier surveys are feasible and repeatable across wide areas of the country (HHP, 2018-2022) and the on-going availability of this information, for both SPAs and the wider countryside, would support adaptive and improved measures for both the hen harrier, forest planners and foresters *e.g.* by inputting locational and breeding status information directly into any Red Areas procedure and these data could also to help inform wider planning decision makers and other sectors to offer improved protection for the hen harrier.

4.6.4 Agriculture

The total SPA population has continued to decline; with a singular site exception of the Slieve Bloom Mountains SPA. These downward trends are despite extensive investment in agricultural supports since the 2015 survey *e.g.* GLAS (Green Low Carbon Agri-Environment Scheme), results based EIPs (*i.e.* HHP); and various protective measures for forestry planning and forestry activity (*e.g.* FS-DAFM's Red Areas Procedure) using spatial and temporal buffers (*e.g.* Higher Likelihood Nesting Areas (HLNAs[6]). The conservation of the hen harrier in Ireland requires urgent finalisation and implementation of the cross-sectoral threat response plan to establish meaningful conservation and sectoral priorities and management measures for the SPAs and wider.

A strategic review of both inputs (both monetary and adopted measures) and outputs (results) from the aforementioned agri-environment programmes for GLAS and HHP, and a robust analysis of results, is required to inform successor programmes such as ACRES and CSP (2023-27), and to ensure that the hen harrier is benefiting from the supporting mechanisms and measures that are in place and funded by the EU and taxpayers. Surveyors have reported an enduring negative perception of hen harrier amongst landowners *i.e.* that the species is responsible for limiting livelihoods and farming aspirations. State funded agri-environment subsidies for farmers and landowners, together with community funding support programmes, are crucial to ensure the roles and skills of locals are supported and valued. A social and supportive culture of farmers and landowners within the SPAs and wider was adopted by the HHP (EIP), an extensive and locally adapted funding programme which ran from 2017-2023 (M. Ruddock, *pers. obs.*). This approach should be encouraged through all programmes including locally-targeted funding opportunities (The Community Environment Action Fund; LEADER programme for Rural Development 2023-2027; Heritage Council).

There is a potential wider issue arising with agri measures (including CAP and EIPs) as they require sustained support over the longer-term, and the timescales of typical supporting 'projects' (often no more than five years duration), may not adequately allow sufficient time for hen harrier population responses. National funding support mechanisms which are targeted, objective-driven, well-designed and practicable, to allow more long-term and consistent hen harrier specific provisions, including those provided via the Common Agricultural Policy (CAP) are necessary.

[6] HLNA are sensitive areas which are identified within SPAs to help avoid forestry-related disturbance which were defined using studies of territorial / nest movements between years which identified nearest neighbour distances from detailed annual studies of the species and the application of a 1.2 km radius as a direct and indirect protective buffer.

The use of machinery and quad bikes across the uplands can cause high levels of disturbance and habitat loss as well as Some targeted and specific management and restoration of sites, including ground-predator exclusion measures for nesting hen harriers, may be required to improve the species locally and to demonstrate best practice opportunities for wider landscape scale recovery. Farming practices and grassland structure and cropping regimes as well as grazing levels can be a particular determinant of grassland and moorland and scrub habitat quality, biodiversity, and carbon capture (Staddon & Faghininia, 2020) for example. It should be noted that some positive changes have occurred in recent years (DAFM, 2022), including the potential eligibility of scrub for Pillar 1 (agri-environment) payments. It is recommended to counteract some of the ineligibility criteria under the previous CAP and increase transfer to heather within incoming CAP frameworks and also and create opportunities for further rewarding of landowners for optimum hen harrier habitats (scrub, heather) and to also discourage the removal of these habitats and also the wider protection and improvement of linear supporting habitat features, such as hedgerows, within wider agricultural policy frameworks. Future measures for hen harrier are needed to broaden and restore semi-natural habitats across their former range to redress the balance of past losses. The Cap Strategic Plan (CSP) should ensure that DAFM advisors, forest planners, Teagasc and the private farm advisor network in Ireland play a role in preventing such losses through a training and upskilling programme delivered by hen harrier ecologists.

4.6.5 Landscape and habitat changes

A key priority is to better understand any causal linkages between the hen harrier population declines and habitat changes at the landscape-scale over time. Further research to assess such habitat changes (including forest maturation) since the previous habitat mapping was completed (Moran & Wilson-Parr, 2015) is needed and the potential influence of such changes on the hen harrier population trends and nesting distribution (Tapia *et al*., 2004) including within the SPA network. This will require examination review of more recent satellite imagery and other relevant datasets (*e.g.* related to forestry, development and planning, wind energy developments, agricultural areas, roads *etc*). This update should also extend beyond the SPAs into the wider countryside and to include the non-designated regionally-important breeding areas. In addition, the functional connectivity of the landscape and habitats with respect to hen harrier needs to be determined incorporating all relevant layers (as described above). The models should factor in variables such as energetic costs, predation risk, and available species location/activity data to predict optimal areas to reconnect and prioritise areas to rehabilitate and/or restore. The development of an integrated GIS mapping resource/tool, showing habitat and land-use information to support hen harrier conservation management planning in Ireland is now required for implementing and targeting future management actions.

4.6.6 Renewable energy

Increasing and extensive renewable energy targets are important to counteract climate change as required through legislation (*e.g.* Climate Action and Low Carbon Development Act 2015) and policy (NAF, 2018; NECP, 2021). Wind energy development, including any future repowering of existing, is likely to increase across our landscapes over the next decade along with associated access and disturbance issues. There are a number of potential impacts on hen harrier from wind energy development (NPWS 2021). A range of negative interactions can occur with wind energy development, including displacement from foraging habitats, avoidance, disturbance at nesting or roosting sites, lower breeding success and mortality (*e.g.* Pearce-Higgins *et al*., 2009; 2012; Wilson *et al.,* 2015; 2016; Fernandez-Bellon *et al.,* 2015; 2018; O'Donoghue *et al*., 2020) surveyors across various regional areas reported widespread breeding season construction works for wind energy developments, and an increasing number of solar energy installations, both during the survey year and increased numbers of developments over recent years since the last national survey. Many surveyors reported that there is poor spatial planning around extant sites and there is persistent loss of suitable hen harrier habitats during wind energy development projects, but particularly in regions of Co. Donegal, Co. Clare, Co. Limerick and Co. Kerry. An increasing number of hen harrier collision

strikes have been reported since the last national survey (NPWS, 2022) and a number of well-used winter roost sites have had turbines constructed within and/or immediately adjacent and resulted in displacement effects on the birds at the roost sites (O'Donoghue, 2021).

4.6.7 Spatial planning

There is a need for consistent and recognised guidance and best practice methods for bird surveys to inform impact assessment (including for hen harrier) in Ireland. That is, to improve upon existing measures in Ireland for spatial planning for various human activities including renewable energy developments (*e.g.* windfarms and solarfarms), forestry and recreation and avoidance of sensitive sites for hen harriers (Currie & Elliot, 1997; Ruddock & Whitfield, 2007; Bright *et al.,* 2008; 2012; Wilson *et al.,* 2016; Caravaggi *et al.,* 2019). Specific guidance for conducting best practice surveys and ecological appraisals and hen harrier work programmes is needed to minimise practical and spatial conflicts across the regions and across the sectors in Ireland, such as potential losses of breeding (and wintering) habitats for hen harriers and ensure adequate baseline information is available for decision makers.

In Ireland for example, afforestation projects may be conducted by personnel with no specific hen harrier expertise but there is no recognised best practice format or template in operation and ecological competences may differ between personnel and require training and/or consultation with appropriate hen harrier expertise. Similarly within development planning and farm advisor networks or recreational event planners across the country a wide range of skills exist but a greater awareness of potential effects of actions or activities and training on the hen harrier is needed through robust survey and spatial planning *e.g.* risk or sensitivity mapping (*e.g.* McGuinness *et al*., 2015). More widely the wind energy work programmes in Ireland, typically follow the best practice guidance in Scotland (SNH, 2017; NatureScot, 2023). These methods may not be as appropriate in Ireland, and/or require modifications, due to variations in *e.g.* breeding or wintering seasons, typical home range size of hen harriers in Ireland, which may be much larger (Irwin *et al.,* 2012) than in Scotland (Arroyo *et al.,* 2009).

Survey guidance and best practice methods for renewable energy developments are required, for pre-construction and post-construction monitoring to improve standardisation and increase efficiency within the planning system for hen harrier ecological assessments. There are opportunities for the wind energy industry to increase levels of land management certainty, and regulation / management of the activities within and surrounding windfarms (*e.g.* recreational users, dog walkers *etc*) and identify opportunities for the retention and restoration of habitats suitable for breeding (and wintering) hen harrier within and surrounding renewable energy developments.

4.6.8 Future research and monitoring

To inform and understand population responses and direct conservation actions, more targeted monitoring at key sites, including the SPAs, is needed along with the continued 5-year national survey model. Developing targeted monitoring of nest locations and breeding outcomes (fledging) at local and regional scales on an annual basis is required to inform conservation decision making *e.g.* buffer avoidance zones for all potential disturbing activities. These measures should include an increase in training and building best practice for surveys and assessment including for foresters, agri-advisors, council planners and developing links between monitoring groups and knowledge transfer.

Following the development of best practice guidance the deployment of a community citizen scientist models, along with improved communication with other ornithologists (*e.g.* consultants), could be linked with local regional experts (*e.g.* NPWS and/or IRSG and/or BWI and/or GET) to corroborate the veracity of records. Such an approach should be reviewed and could conceivably collect a high proportion of the necessary hen harrier population data annually. This information would enable wider and more bespoke safeguards and extend

protection measures beyond SPAs providing more strategic consideration of spatial and temporal sensitivities to help inform sectoral responses and adaptations.

Specific research measures or outputs are required to improve the estimates of population modelling and the collation of all historical and extant hen harrier research data, through the agreement with multiple stakeholders, to inform more detailed understanding of regional projections of population changes (see Fielding *et al.,* 2011). Monitoring of hen harriers and their habitats and changes requires further consideration and an annual review of the adequacy of monitoring changes in both birds and habitats over time are needed and to assist identifying any information gaps and be developed alongside mapping tools and resources. As outlined above the next annual survey is recommended to take place in 2025.

There is a need for a better understanding of the lack of hen harriers in vacant areas with apparently high suitability of habitats for harriers, such as the Wicklow Mountains, could provide opportunities for restoration of the species range and abundance *e.g.* through reintroduction or translocation using best practice guidance for such ex-situ conservation measures (IUCN, 2013). The guidance requires that the reasons for extirpation in the first instance are not going to reoccur and appropriate policies are in place to address the existential threats and pressures to avoid subsequent failure of the reintroduction or translocation. Such conservation measures would require extensive review, stakeholder consultation and consideration before implementation.

Future research of SPA and nest site-specific management measures, and the learnings of from the HHP (*e.g.* Wilson-Parr, *in prep.*) with respect to supporting actions and measures implemented by that project and best practice opportunities would help improve linkages in understanding and reversing some of the direct causes of failure. This includes measures to prevent and better protect nests sites which are failing late in the breeding cycle and specific measures to be implemented to improve fledging success. The information derived from the 2022 national survey and comparative earlier surveys about the potential shifting of sex ratios based on those observed birds may relate to wider causes of mortality. For example, further research may be needed to understand the causes and drivers of the sex-biased sightings recorded, which may be due to a number of factors including survival (at nesting, post-fledging or post-dispersal stages) or the occurrence of environmental contaminants (*e.g.* rodenticides and plant protection products) in the wider landscape.

4.7 Recommendations

The hen harrier population is severely affected by a range of activities, pressures, and threats across Ireland. The population has declined substantially in the short-term 2015 to 2022 by one third and in the long-term 1998/2000 to 2022 by more than half and the species needs specific, targeted, and expeditious actions across the species' range and by stakeholders. A cohesive, collaborative approach is required to collectively reverse the decline of the species to ensure that the hen harrier does not become ecologically defunct, or extinct, within any region or nationally.

NPWS and key Government Departments are developing a Hen Harrier Threat Response Plan (HHTRP) in consultation with stakeholders and the public to cease, avoid, reverse, reduce, eliminate, or prevent threats on the hen harrier (NPWS, 2024). The legal basis for the HHTRP is established in Regulation 39 of the European Communities (Birds and Natural Habitats) Regulations 2011 (SI No. 477)[7]. NPWS has also published the conservation objectives for the hen harrier SPAs and the SPA network as a whole (NPWS, 2022).

Fernandez-Bellon *et al.* (2021) suggests that effective conservation of hen harrier populations should prioritise active management strategies rather than passive protection measures. Measures to conserve and restore hen harrier populations need to be locally-adapted, site-

[7] *S.I. No. 477/2011 - European Communities (Birds and Natural Habitats) Regulations 2011* https://www.irishstatutebook.ie/eli/2011/si/477/made/en/print

specific and targeted at various levels, *i.e.* localised, regional, and national populations, delivering. Hen harrier conservation in Ireland requires urgent implementation of concrete and significant actions promptly to prevent its further deterioration. Many of the required actions to improve the conservation status of hen harrier are identified in the HHTRP, here we outline specific recommendations arising from the national survey to inform the protection and restoration of the hen harrier population in Ireland.

- Urgent and specific interventions for the hen harrier are required in Ireland, including the prompt implementation of a robust and effective HHTRP to address population declines.
- Regular National Surveys are required (every 5 years), returning to the schedule as indicated prior to the Covid-interruption. Thus the next survey would take place in 2025.
- Survey data evaluation must continue to include subset analysis to ensure like-for-like comparisons between survey.
- The conservation status of the hen harrier must be continually assessed, utilising best available data. In forthcoming BOCCI reviews, it is recommended that the subset analyses (which demonstrate a >50% decline) be used to assess population changes.
- Annual monitoring is required for the hen harrier and opportunities for increased levels of interannual surveys, databases, and reporting, both within and outside the SPA network, including with the greater involvement of citizen scientists and new technologies (*e.g.* remote sensing) should be explored. This will provide better data to inform decision making across sectors within the species' range, including forestry, renewable energy, agriculture, and recreation.
- Given the status of the hen harrier and observations from surveyors in the 2022 survey, the protections for hen harrier currently in place needs to be reviewed and expanded upon. Many wide-ranging stakeholders interact with hen harrier conservation needs, including but not limited to forest, agriculture, renewable energy, and recreation sectors. Inclusive consideration of the threats and pressures, and actions that can be taken to improve its conservation status is required including within the HHTRP.
- In order to alleviate current pressures, *i.e.* disturbance during the breeding season due to forest management operations, a review of methods and protocols of hen harrier forestry protection measures is warranted, *i.e.* the FS-DAFM Red Area Procedure including the potential extension of protection measures to hen harrier breeding habitat outside the SPAs and implementation of additional measures to prevent the loss and deterioration of hen harrier habitats and direct disturbance of breeding sites.
- A review of the afforestation protocols, the survey methods and guidance used to inform such protocols, and other forest management activities in accordance with the legal obligations under the Wildlife Acts and the Birds and Natural Habitats Regulations, is warranted.
- Upskilling and training of foresters and ecologists involved in the preparation of impact assessments, in hen harrier ecological requirements is recommended.
- The deployment of annual and/or site-specific surveys for forestry and/or afforestation licences and the mitigation measures required should include consultation with relevant hen harrier expertise and recommend the formation of a working group to review this to include all relevant stakeholders.
- A review of the best available scientific evidence and data collection protocols, and data availability and sharing, to inform forest sector actions and activities is recommended and the deployment of annual surveys and/or site-specific surveys to ensure data are current and relevant for forest management activities and seasonal activities are in accordance with the Wildlife Acts and Birds and Natural Habitats Regulations.

- The agricultural sector has significant capacity to implement landscape scale changes that can be optimised for the hen harrier. The removal of any remaining conflicts within funding systems (*e.g.* scrub and heather eligibility) and their effective communication to agri-advisors and participants to prevent on-going loss and disturbance of breeding hen harrier and their habitats is recommended.
- Long-term support for local communities and locally adapted agricultural programmes is needed; farmers and land managers should be centrally positioned within these; and sufficient supports by way of knowledge sharing (in both directions) and monetary inputs should be provided via the community sector through local engagement mechanisms, to minimise negative perceptions of hen harrier conservation to reduce the negative sentiments towards the species across all sectors.
- As with the forest sector, it is recommended that the agricultural sector reviews methods and protocols for hen harrier nest protection measures (*i.e.* avoiding disturbance to nest sites) both inside and outside the SPAs, as well as implementing additional measures to prevent the loss and deterioration of hen harrier habitats, the direct disturbance of breeding sites, and to minimise potentially disturbing activities, particularly those involving machinery during the breeding season, as may be required and in accordance with the Wildlife Acts and Birds and Natural Habitats Regulations.
- The Cap Strategic Plan (CSP) should take into account the importance of supporting habitats and features for hen harrier in the wider landscape and include the provision of training and upskilling of agricultural advisors with respect to the ecological requirements of hen harrier.
- A cessation of cutting and burning of deep heather across Ireland is needed and clarity regarding ineligibility criteria of deep heather within farming subsidy frameworks is required. Disincentivising these actions, more effective communications by farm advisory, and the enforcement of the relevant nature legislation may be key in preventing these habitat losses. More action is required to address the loss of habitats through turf-cutting at inappropriate locations, by machinery and/or at critical times of the year and preventing disturbance in accordance with the Wildlife Acts and Birds and Natural Habitats Regulations.
- There is a need for long-term and consistent supports (greater than five years) a within the agricultural sector to implement ecologically-meaningful actions for the hen harrier.
- There are opportunities for knowledge transfer and skill sharing between hen harrier ecologists and the farm advisor networks to increase awareness across the species' range and provide significant levels of interaction, sightings and opportunities with landowners and farmers.
- The 2015 published habitat mapping for the SPAs needs to be updated and it is recommended that it be expanded to include the non-designated regionally important areas.
- In tandem with the habitat map update, research that examines land-use and habitat composition and suitability for hen harrier in the wider landscape and how these are likely to influence movements and population dynamics of hen harrier should be initiated.
- A programme using the learnings from habitat suitability research (see above) to work collaboratively with other relevant and existing projects and stakeholders to develop pilot studies and targeted rehabilitation/restoration measures at hen harrier study / trial sites, perhaps initially comprising groups of existing nests, which would then act as best practice demonstration sites and provide 'hot-spots' of hen harrier productivity.
- It is recommended that these restoration sites are implemented at an appropriate scale in the landscape and target measures to increase fledging success of the hen harrier. Protection from predation and disturbance between the nestling and fledgling stage will

be a key measure to reverse the population decline by increasing productivity (see also Ruddock *et al.*, 2016).

- Disturbance and habitat losses with the hen harrier range from land-use changes and development activities must be reduced.
- The development of best practice guidance for surveying hen harriers in Ireland is needed for the renewable energy sector. This should give due consideration to specific assessment and reporting needs for hen harrier including best practice developed in other jurisdictions, with a view to producing bespoke Irish guidance.
- Since recreation has been highlighted through surveyor observations in 2022, as increasing since 2015, and problematic at breeding sites it is recommended that further exploration is also taken forward by relevant stakeholders and Government Departments to consider how best to quantify and alleviate this pressure.
- A programme of awareness and education within the recreational sector in particular is recommended, focussed on dog walking, scramblers and off-road vehicle usage within the uplands and breeding ranges of the hen harrier and also with regard to the development of projects, trails and tracks within hen harrier areas.
- A programme and best practice of survey and assessment for recreational user groups could be adopted to help minimise the interaction between the hen harrier and events or group activities and development or update of risk / sensitivity mapping would provide a key resource to assist event planners.
- The key recommendations proposed by recent Irish hen harrier research (either published or in preparation), including on wintering ecology (O'Donoghue, 2021), seasonal ecology (McCarthy, 2022) and agri-ecology (Wilson-Parr, in prep) should be considered and implemented.
- There are additional research needs that must be met in order to address key knowledge gaps identified in this report, including the following; a specific focus on research determining causes of observed sex ratio imbalance; developing habitat suitability models; examining prey availability influence on hen harrier nesting distribution and breeding success; investigating rodenticide effects on the hen harrier and a review of all available information and research and horizon scanning of future needs.

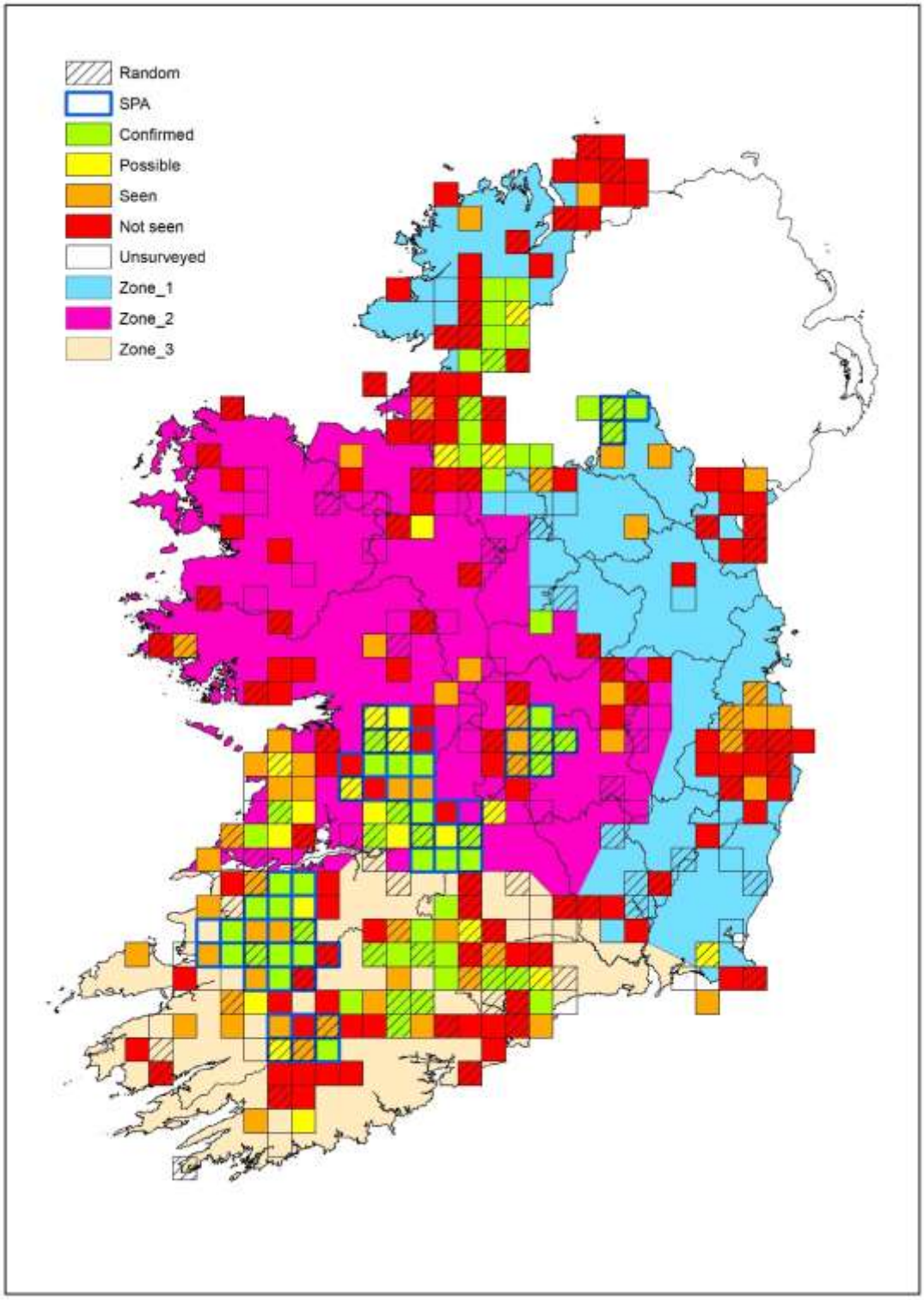

Figure 1 The 10km squares selected for survey during 2022, including the historical maximum breeding status (1998-2021 inclusive), 10 km squares overlapping with SPAs and randomly selected squares.

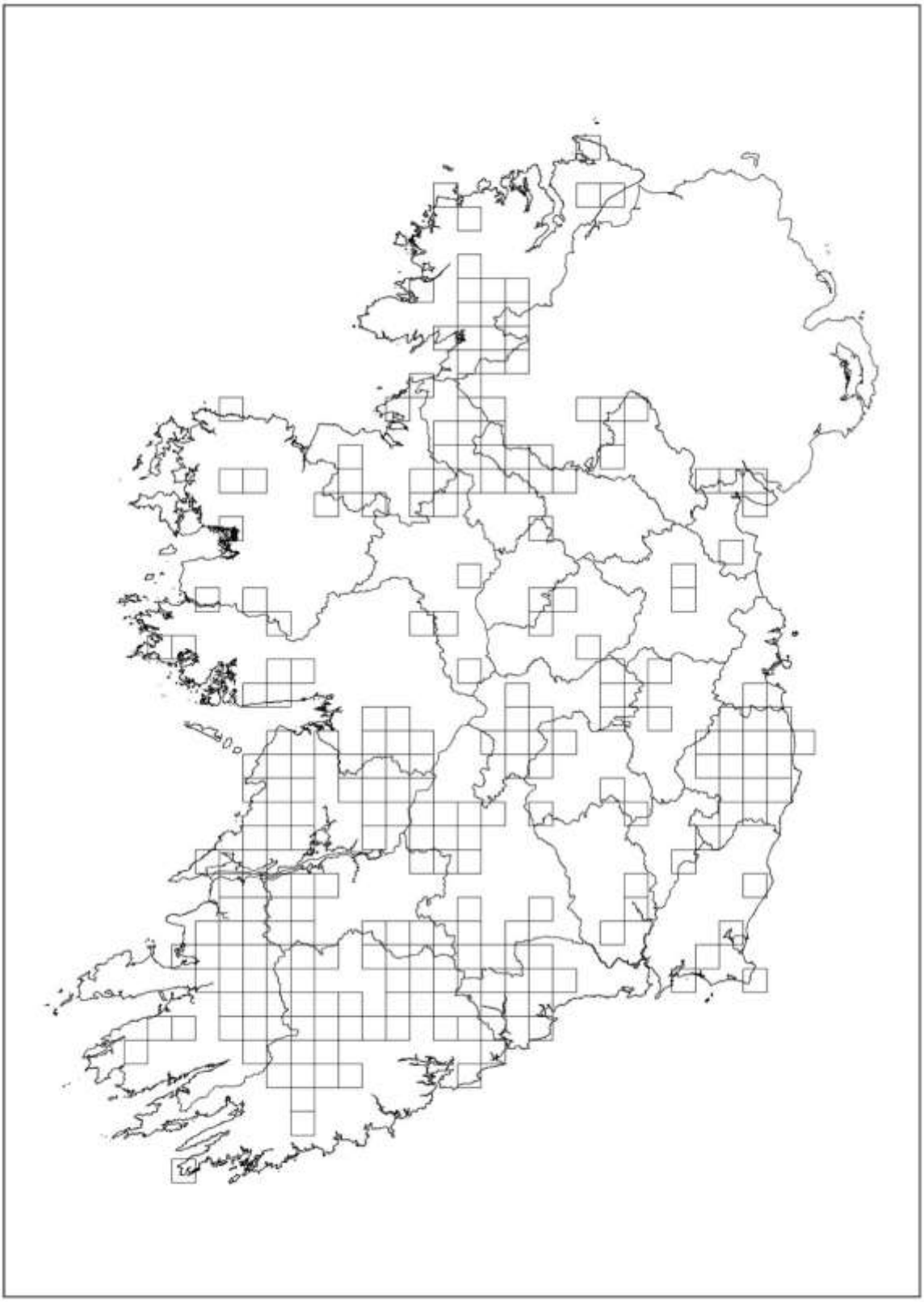

Figure 2 Distribution of survey squares covered during 2022 for which data was received.

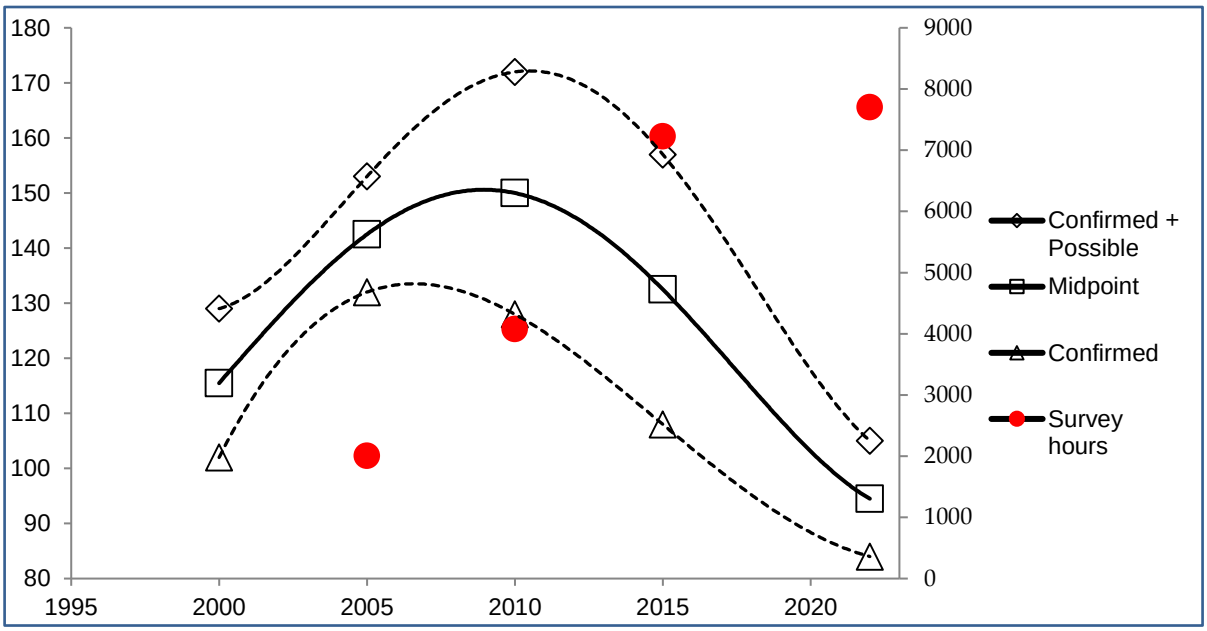

Figure 3 Graph showing the recorded population range and mid-point estimates, trendlines and survey effort over the national hen harrier surveys.

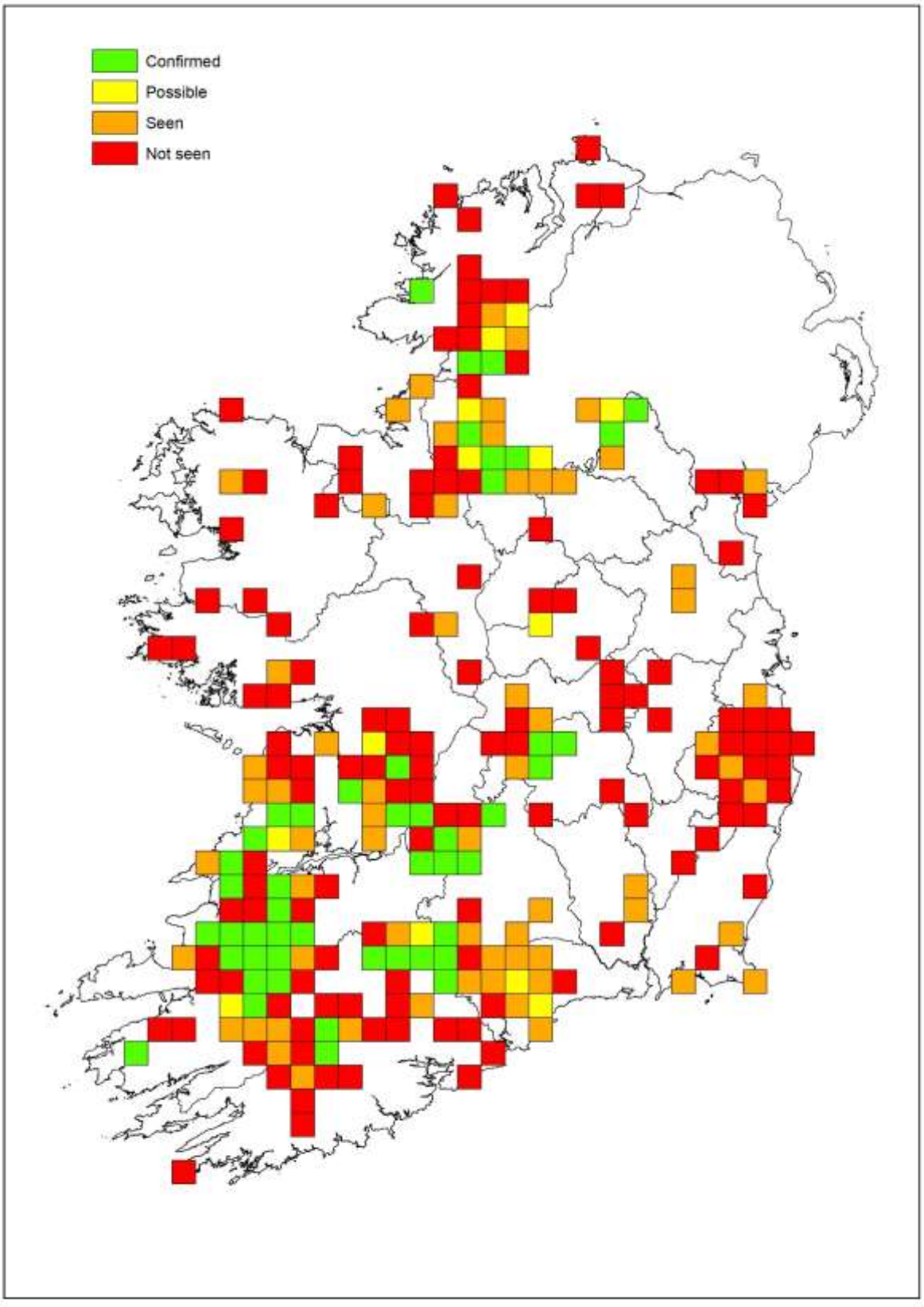

Figure 4 2022 distribution of breeding hen harrier in Ireland in 10 km squares, classified by breeding status.

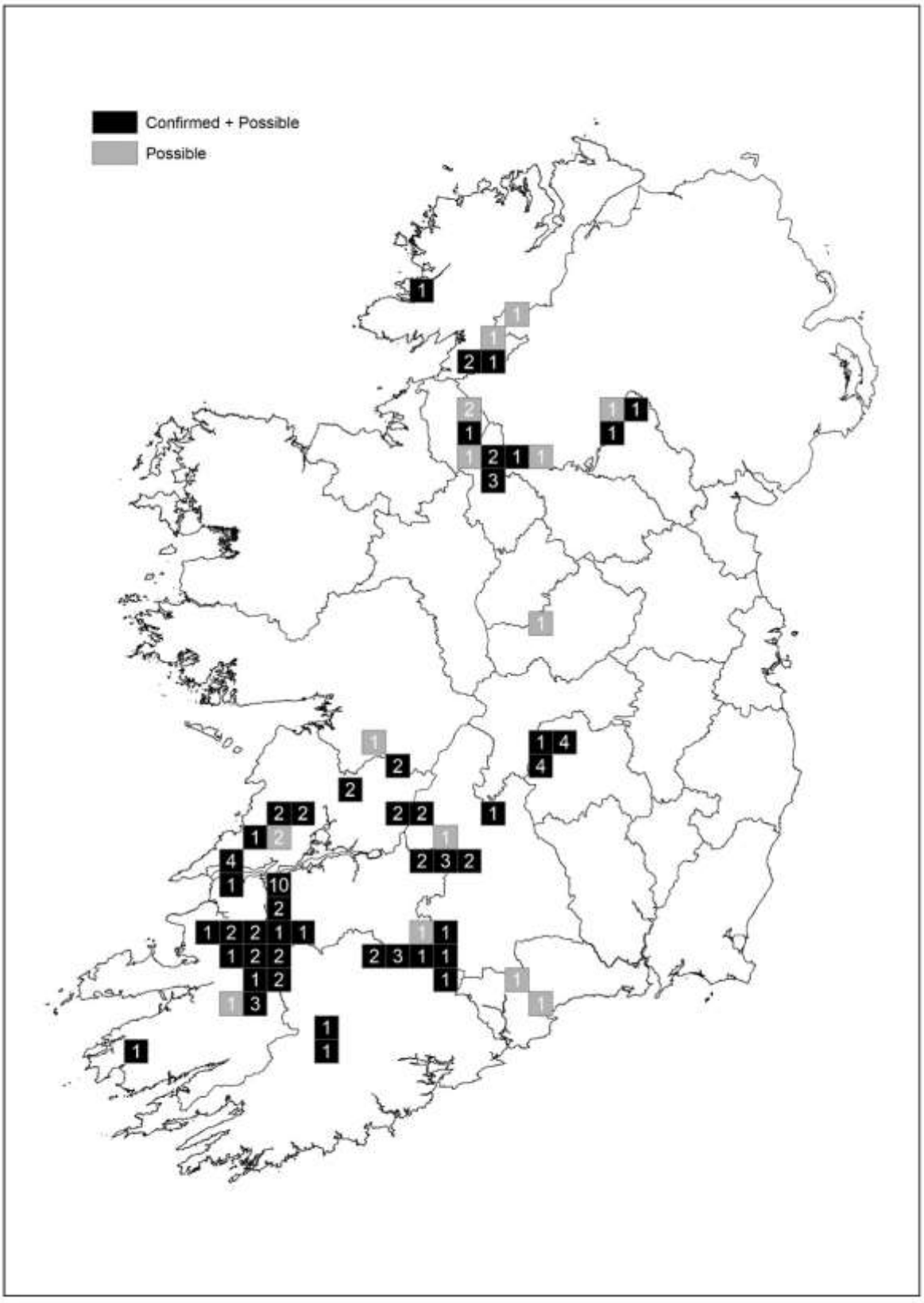

Figure 5 The distribution (at 10 km square level) and numbers of confirmed and possible breeding hen harrier in Ireland during 2022. Black squares show total number of pairs (confirmed + possible) and grey squares show total number of pairs (possible only).

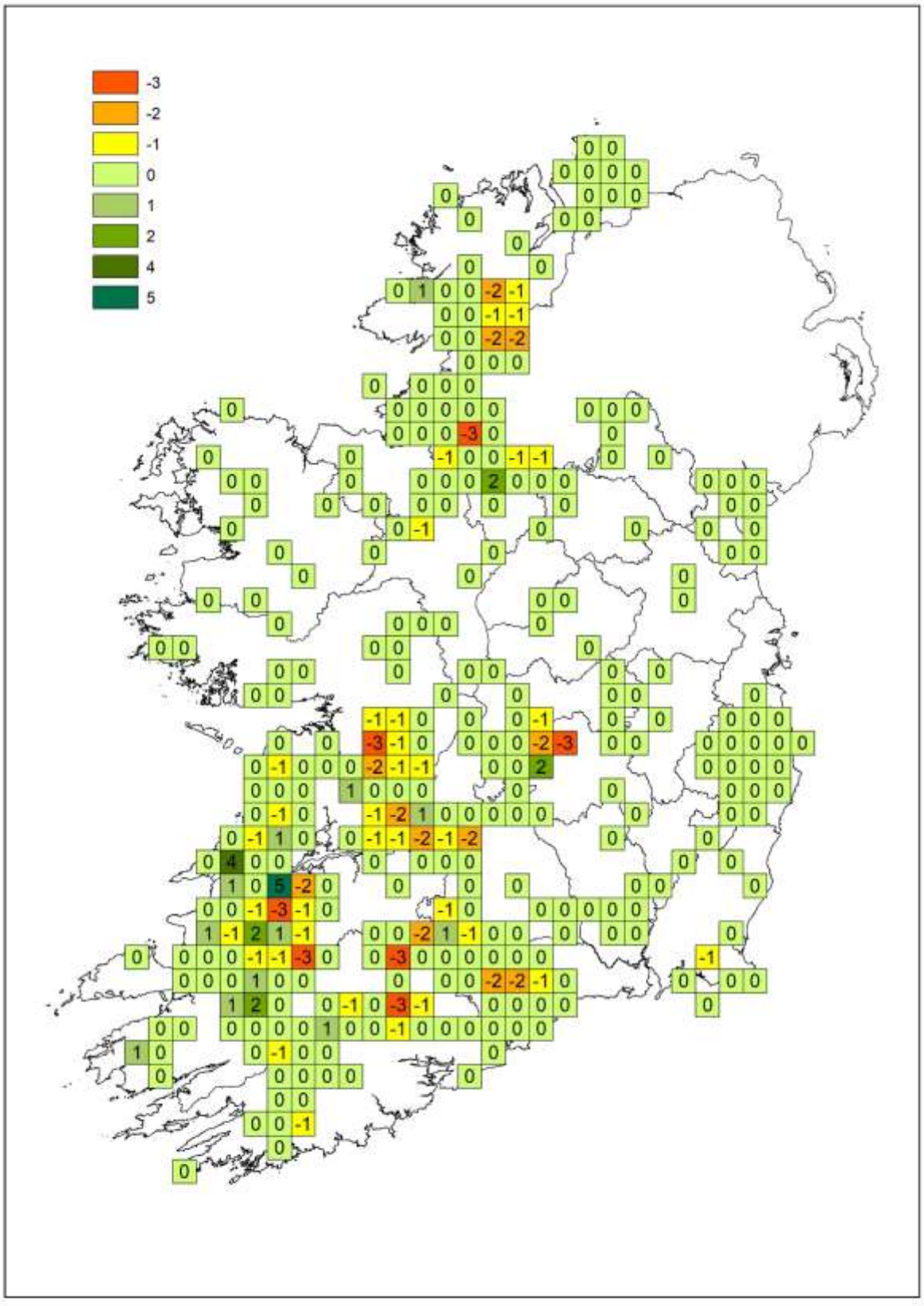

Figure 6 The changes in distribution (at 10 km square level) and numbers of breeding hen harrier in Ireland between 2022 and 2015.

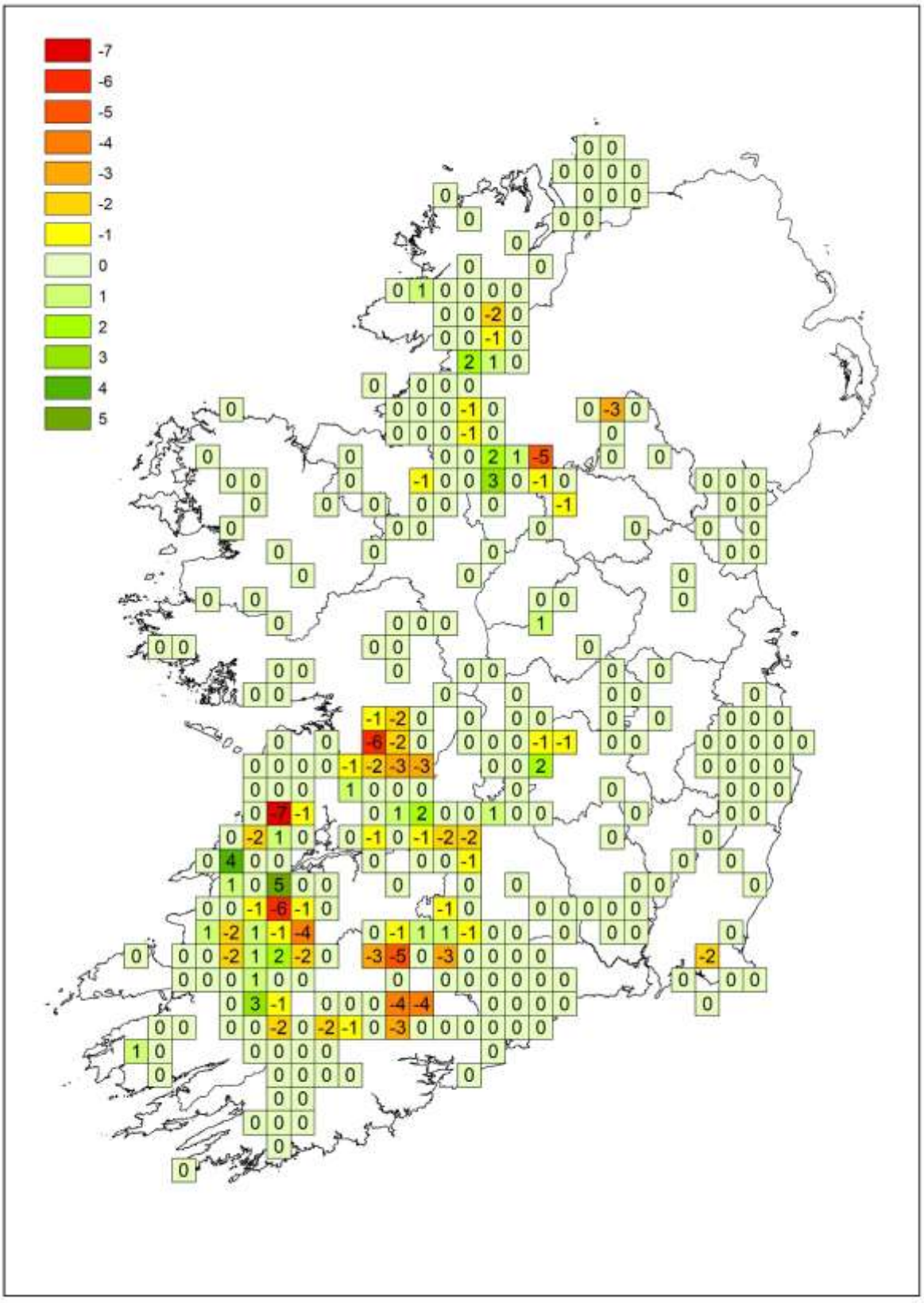

Figure 7 Maps showing population stability, increase and/or decrease across 10 km squares between surveys in 2022 and 2010.

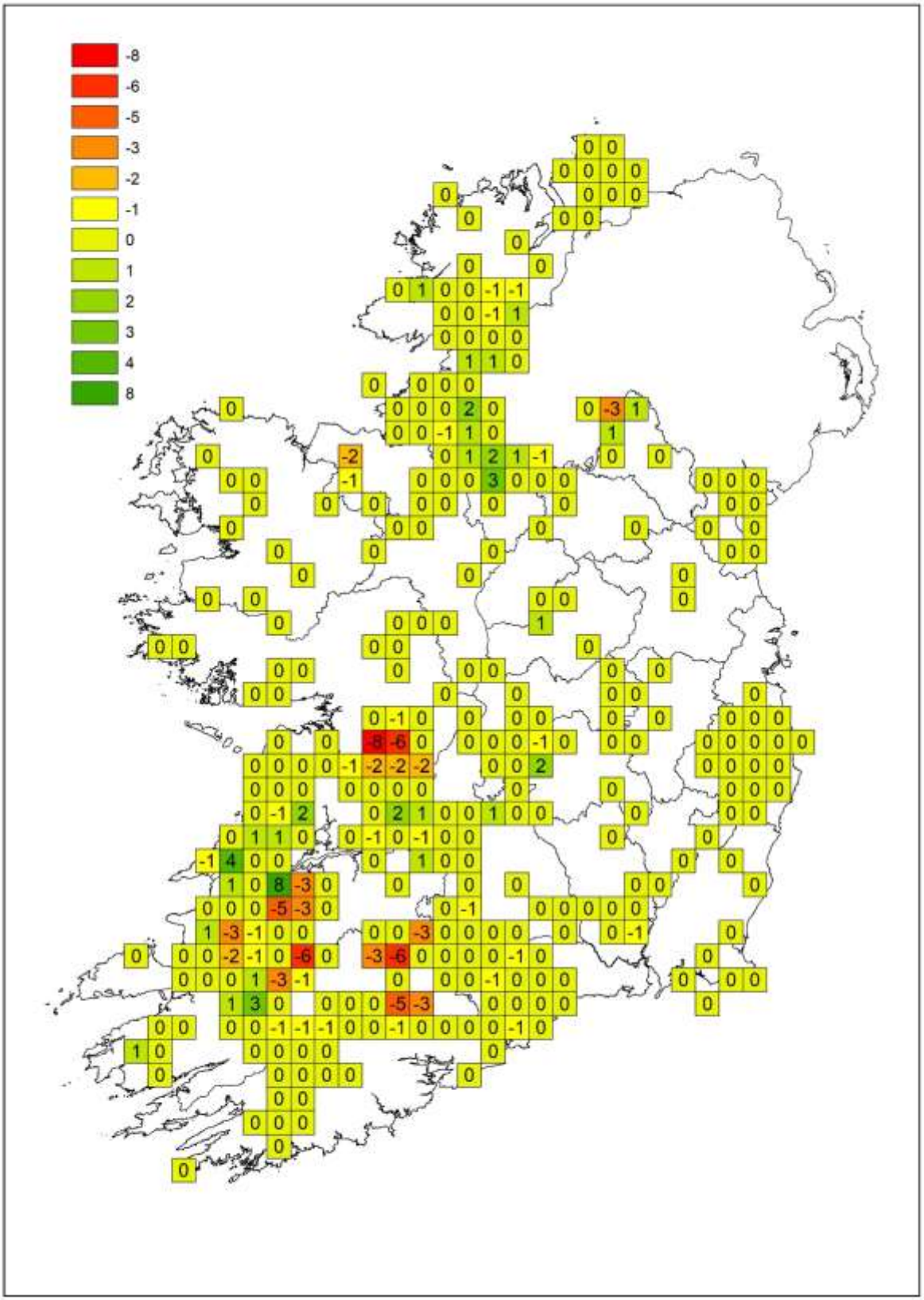

Figure 8 Maps showing stability, increase and/or decrease between surveys in 2022 and 2005.

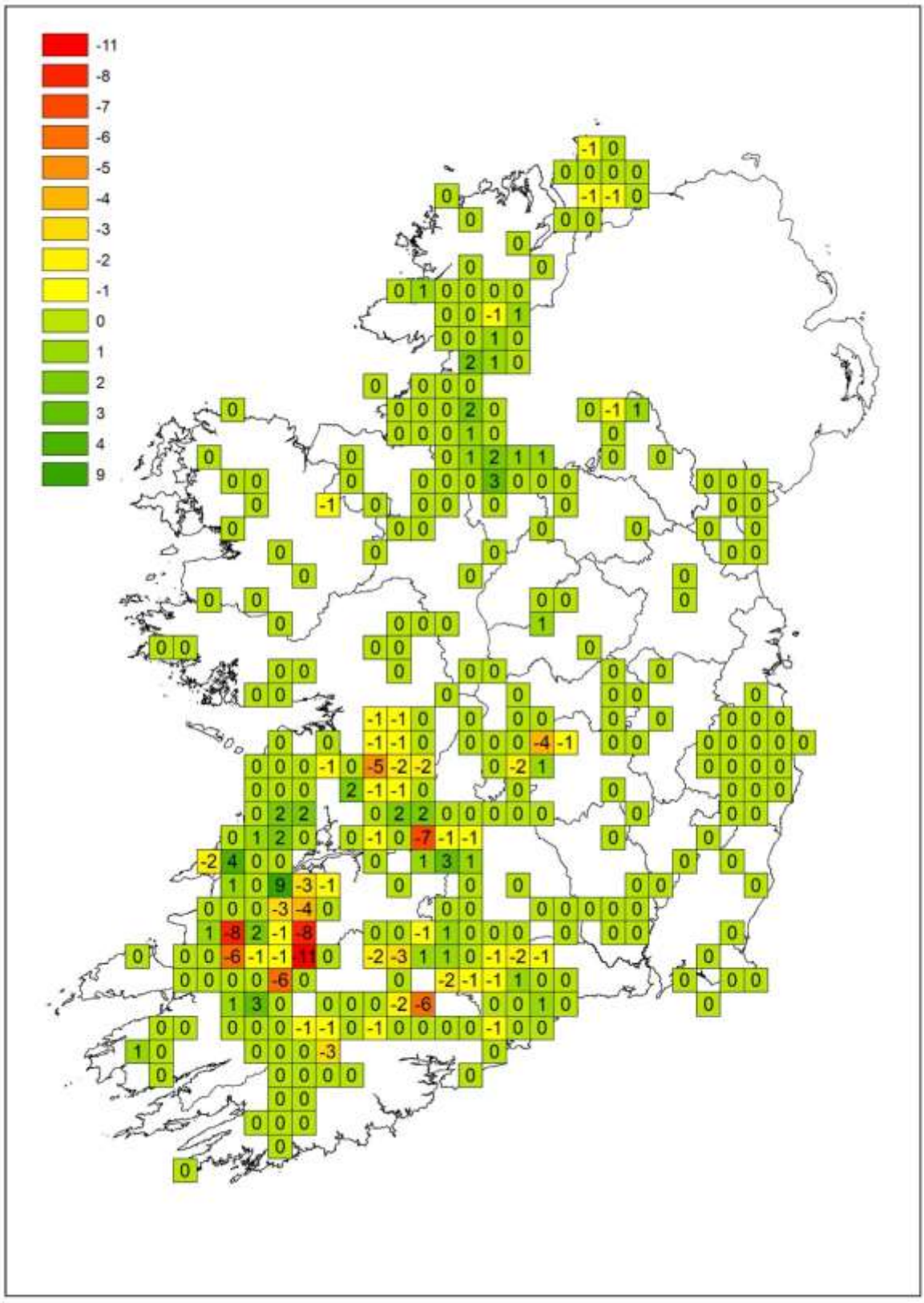

Figure 9 Maps showing stability, increase and/or decrease between surveys in 2022 and 1998–2000.

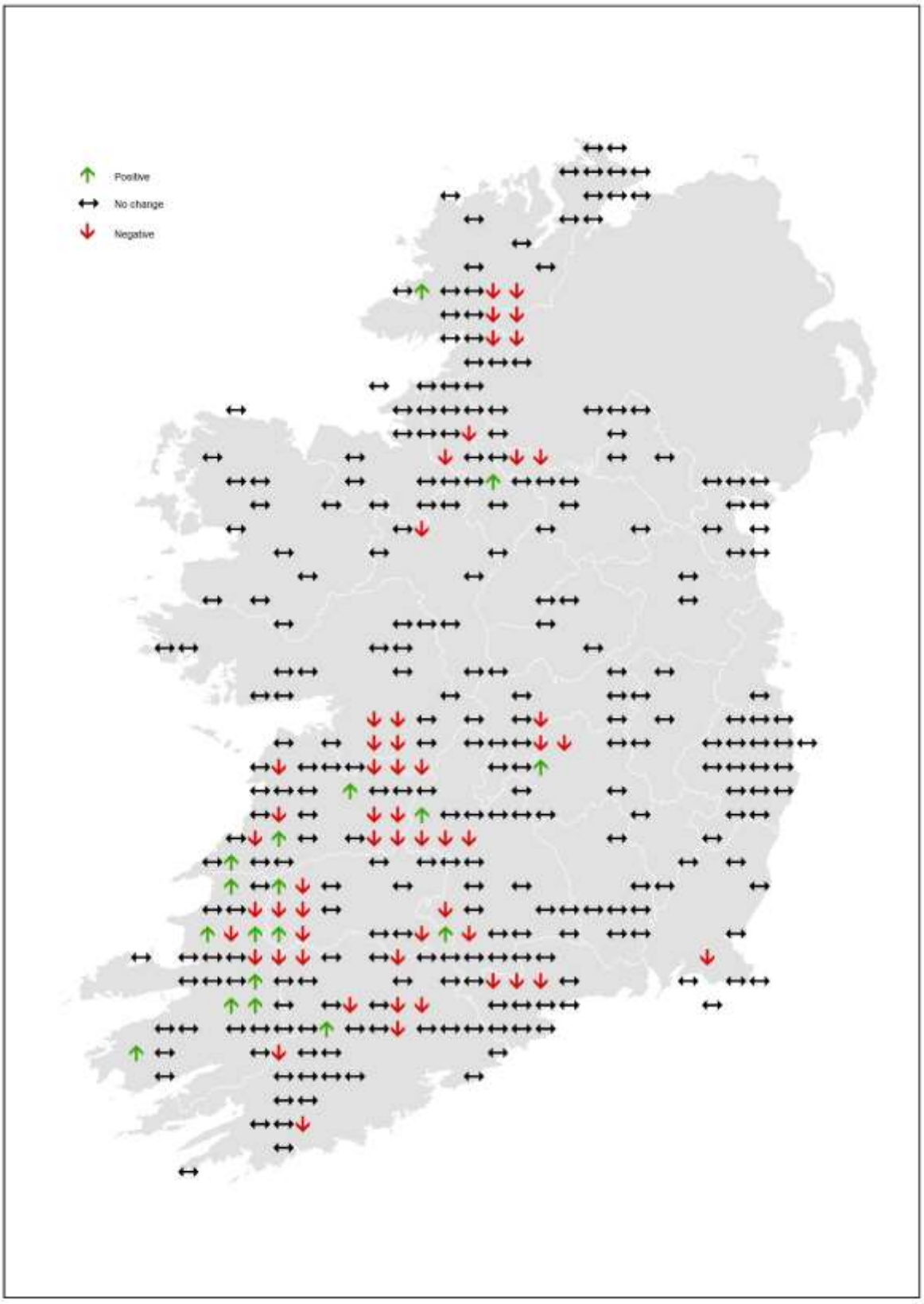

Figure 10 The changes in distribution and numbers of breeding hen harrier in Ireland between 2022 and 2015, showing direction of change in numbers.

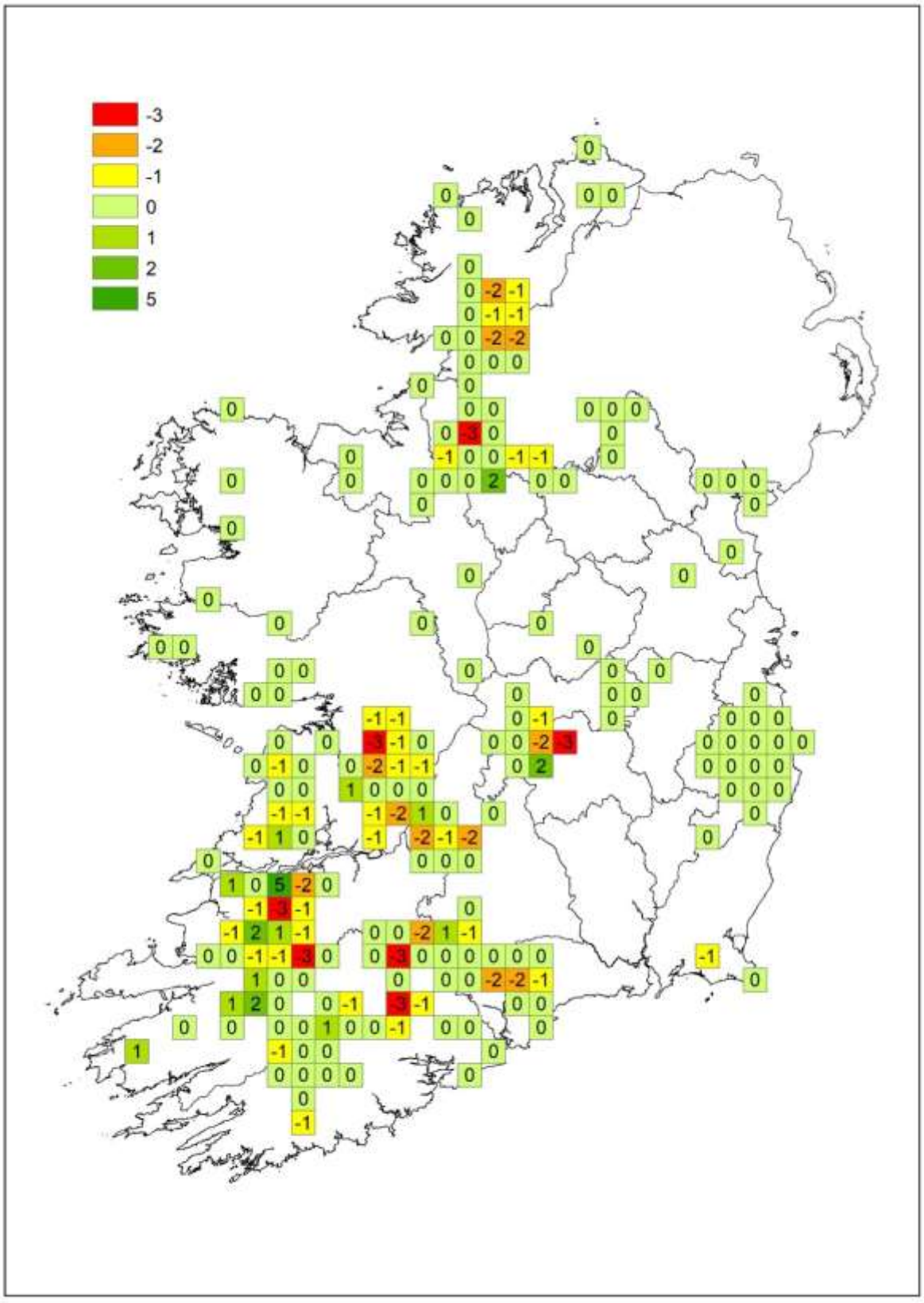

Figure 11 The changes in distribution and numbers of breeding hen harrier in Ireland between 2010 and 2015 in the subset of squares (n = 212) surveyed in both 2022 and 2015.

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

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

Table 2 Behaviour codes and descriptions utilised during the survey.

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

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 >1 m tall with large open spaces between lines of planting.
Second rotation forest (2F)	Second-rotation forest plantations before canopy closure. Characterised by varying shrub layer development and brash and tree root-plates from the previous crop and large open spaces between lines of planting. Newly established second-rotation trees are not always obvious. Third rotation crops are likely in future years but none were recorded in this survey.
Thicket (pole) or mature stage forest (T)	Closed-canopy forest plantations including both 1F & 2F crops. Usually >10 years old. Characterised by absence of shrub layer, except in rides between stands of trees and in small patches of unplanted ground or failed crop.
Clearfell (CF)	Harvested plantation not yet restocked with trees. Characterised by limited development of herb and shrub layer, and brash and tree root-plates evident from the previous crop.
Heather moorland/bog (H)	Unenclosed heather-dominated moorland characterised by species such as heather, bilberry and purple-moor grass plus blanket bog characterised by ling and bell heather, bog cotton, deer grass and moss. Typically grazed by red deer and low densities of sheep.
Grass moorland (G)	Unenclosed grass-dominated moorland usually grazed by sheep. Characterised by species such as wavy hair grass, mat grass and heath rush. Stands of rush (*Juncus* spp.) and bracken (*Pteridium* spp) occasionally occur.
Rough grassland (RG)	Unenclosed or enclosed, neglected pastures occasionally stocked with sheep or cattle that have not recently been improved, re-seeded or fertilised. Usually contains long grass, waterlogged areas and stands of rushes (*Juncus* spp).
Improved grassland (IG)	Enclosed pastures that have been drained, fertilised or re-seeded characterised by lush green grass vegetation and containing higher densities of sheep or cattle. Also includes hay meadows.
Scrub (S)	Areas outside or away from plantation forests consisting of willow, bramble, furze *etc* which have not been tended by humans. Includes bushy vegetation such as willow (*Salix* spp), gorse (*Ulex* spp), bramble (*Rubus* spp), alder (*Alnus* spp), birch (*Betula* spp) and bracken (*Pteridium* spp).
Linear feature associated with rough grassland (LR)	Linear feature (*e.g.* hedgerows, ditches and drainage channels) that are contained, or in close proximity to, rough grassland
Linear feature associated with improved grassland (LI)	Linear feature (*e.g.* hedgerows, ditches and drainage channels) that are contained, or in close proximity to, improved grassland
Other (O)	Description of habitat where it does not fall into one of the categories outlined above.

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 harrier

Table 5 Details of information requested to be collected by the surveyors on recording forms and digital data entry portals.

Data Entry Item	Description
Name	the name(s) of observer name surveying the 10 km square
Email	the observer email address for follow up contact if required
Number of pages	the number of pages and current page number *e.g.* page 1 of 2, 2 of 2 *etc*
Organisation Name	the name of the organisation or study group to which the observer(s) belong
Phone number	the phone number of the surveyor
Observation Type	the type of observation (please tick) which should be either i) casual or ii) vantage point observation
10 km Square	the 10 km grid reference of the square (1 letter & 2 numbers)
County	the county in which the 10 km square is located
Survey Area Name	the survey area name *i.e.* nearest place name or townland to the surveyed area (taken from the survey map)
Activity / Pressure / Threat	the activities/threats or pressures observed, if any, within 500 m and within 2 km of the survey area
Visit Number	the visit number *i.e.* whether visit 1, 2, 3 or 4 on the survey schedule
Date	the date please use the following format *e.g.* 01 06 = 1st June
Vantage Point Location	the vantage point grid reference (1 letter & 6 numbers). Specify the location from which your observation was made
Start Time	the start time of your vantage point watch or observation, this helps us understand survey effort
End Time	the end time of your vantage point watch or observation, this helps us understand survey effort
Sighting Time	the sighting time insert the time at which you saw the hen harrier(s) or the other species
Sighting Grid Reference	the grid reference of the sighting (1 letter & 6 numbers). Specify the grid reference of mid-point of activity where it occurs over a large distance or in multiple locations by the same pair/individual. Please specify clearly the grid reference of the nest (if located) and mark this on your map with an X. This data will all be kept confidentially.
Hen Harrier Number	the hen harrier numbers are to identify the number of individuals (0, 1, 2, 3 *etc*) seen during each sighting of each age group and sex.
Behaviour Code	the behaviour code(s) (see Table 2), please record all behaviours noted during sighting, you can record multiple behaviour codes here. The more information you provide the more useful your sightings will be during analysis
Habitat Code	the habitat code(s), which is the dominant habitat within 100m of the sighting or nest (see Table 3)
Other Species Code	the other species code(s) which are to record any other raptors, waders or priority species encountered during surveys. The main focus of the survey is for hen harrier but since surveyors will be widely dispersed over the country this is an opportunity to collect some additional information on some priority bird species. Please focus survey effort on hen harrier but it is useful to record any casual sighting time, sighting grid reference, behaviour codes and habitat codes also for some of the other species. BTO species codes are provided on the recording form.
Survey Area Summary	the survey area summary is to help inform us what your perception of the sightings and activity are at each of your surveyed areas and to

Data Entry Item	Description
	advise how we should classify each of your survey areas; these should be classified according to Table 6.
Notes	the notes section is to allow the addition of any relevant information. In particular, this should include any suspected persecution of hen harrier or disturbance, or poor weather recorded during your fieldwork, details of any wing tagged hen harrier should also be recorded to include colour of left-wing tag, colour of right-wing tag and any codes on the tags

Table 6 National (minimum, maximum and mid-point) population estimates between 1998-2000 (Norriss *et al.,* 2002); 2005 (Barton *et al.*, 2006); 2010 (Ruddock *et al.*, 2012), 2015 (Ruddock *et al.,* 2016) and 2022 (this study).

Breeding Status	1998-2000	2005	2010	2015	2022	% change 2015 - 2022
Confirmed	102	132	128	108	85	-21%
Possible	27	21	44	49	21	-57%
Confirmed + Possible	129	153	172	157	106	-33%
Mid-Point	115.5	142.5	150	132.5	95.5	-28%
Range	102-129	132-153	128-172	108-157	85-106	-

Table 7 Number of 10 km squares by breeding hen harrier status in Ireland during survey periods.

Breeding Status	1998-2000	2005	2010	2015	2022	% change 2015 - 2022
Confirmed	42	60	62	62	48	-23%
Possible	17	6	7	22	13	-41%
Range	42-59	60-66	62-69	62-84	48-61	-27%

Table 8 Change in distribution and abundance of hen harrier within subset analyses between 2022 and previous national surveys

	i (2002-2015)	**Change (%)**	**ii (2022-2015-2010)**	**Change (%)**	**iii (2022-2015-2010-2005)**	**Change (%)**	**iv (2022-2015-2010-2005)**	**Change (%)**
Number of squares surveyed	212		125		105		74	
Confirmed (2022)	79		72		63		54	
Possible (2022)	21		20		18		10	
Total	100		92		81		64	
Confirmed (2015)	107	-26.2	99	-27.3	95	-33.7	78	-30.8
Possible (2015)	47	-55.3	41	-51.2	34	-47.1	24	-58.3
Total	154	-35.1	140	-34.3	129	-37.2	102	-37.3
Confirmed (2010)			127	-43.3	117	-46.2	100	-46.0
Possible (2010)			43	-53.5	39	-53.8	32	-68.8
Total			170	-45.9	156	-48.1	132	-51.5
Confirmed (2005)					125	-49.6	110	-50.9
Possible (2005)					19	-5.3	17	-41.2
Total					144	-43.8	127	-49.6
Confirmed (1998-2000)							110	50.9
Possible (1998-2000)							45	-77.8
Total							155	-58.7

Table 9 Regional population estimates during 2015 utilising the squares as defined in 1998-2000, 2005 and 2010 for regional mountain ranges or site complexes.

Region	Total pairs 1998-2000	Total pairs 2005	Total pairs 2010	Total pairs 2015	Total pairs 2022	Trend since 2015	Change since 2015 (%)
Ballyhouras	6-8	17-19	10-15	10-12	6-7	↓	-42%
Blue Stack Mountains, Pettigo Plateau & South Donegal	1	3-5	4-5	8-12	4-6	↓	-50%
Boggeraghs, Derrynasaggarts	4-5	5	6-8	2-4	5	↑	25%
Castlecomer, Blackstairs, Kilkenny	0	1	0	0	0	=	0%
Curlew Mountains	-	-	0	0	0	=	0%
Devilsbit, Slievefelim, Silvermines, King Hill*	5-7	7-8	10-14	7-15	9-10	↓	-33%
East Cork & Waterford	0-1	2	1	1	0-1	=	0%
Galtys	0	3	5-6	2-3	2	↓	-33%
Inishowen Peninsula	1-3	0	0	0	0	=	0%
Kildare	-	-	0	0	0	=	0%
Knockmealdowns, Kilworth, Comeraghs	3-7	2-4	2	5-7	1-2	↓	-71%
Leitrim, Slieve Rushen, Cavan	0	3	12-14	9-15	7-11	↓	-27%
Longford, Roscommon	0	0	0 – 1	0-1	0	↓	-100%
Nagles	3-5	9	7-11	5	0	↓	-100%
North & west Clare	1-2	5	12-16	3-9	4-7	↓	-22%
North-west	-	-	0	0	0	=	0%
Ox Mountains, Sligo	0 - 1	1-3	0	0	0	=	0%
Slieve Aughties	10-21	24-27	16-24	8-14	3-5	↓	-64%
Slieve Beagh	3	4	5-6	3	2-3	=	0%
Slieve Bernagh to Keeper Hill	1	1-2	2	5-7	2-4	↓	-43%
Slieve Blooms	10-11	5-8	9	11-12	8-9	↓	-25%
Stack's, Glanarudderies, Knockanefune, Mullaghareirks, North of Abbeyfeale	38-45	40-45	25-36	25-31	27-28	↓	-10%
West Cork	0	0	0	0-1	0	↓	-100%
West Kerry	-	-	0	0	1	↑	100%
Wexford	-	-	1-2	0-1	0	=	-100%
Wicklow Mountains	0	0	0	0	0	=	0%
Other Areas**	-	-	0	4	5-6	↑	50%
Total Numbers	102-129	132-153	128-172	108-157	85-106	↓	-33%

Table 10. Numbers of confirmed and possible hen harrier territories within the boundaries of each of the six breeding hen harrier SPAs.

SPA	2000*	2005	2010	2015	2022	Change (2005 – 2022)	Change (2010 – 2022)	Change (2015 – 2022)	Change % (2005 - 2022)
Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle (4161)	41	40-45	18-29	23-28	21	-24	-8	-7	-53%
Mullaghanish to Musheramore Mountains (4162)	3	5	2-3	1	1	-4	-2	0	-80%
Slievefelim to Silvermines Mountains (4165)	8	4-5	6-7	4-10	3-4	-1	-3	-6	-20%
Slieve Bloom Mountains (4160)	11	5-8	9	12-13	8-9	1	0	-4	12%
Slieve Aughty Mountains (4168)	21^	24-27	15-23	8-14	3-5	-22	-18	-9	-67%
Slieve Beagh (4167)	3	4	5-6	3	2-3	-1	-3	0	-25%
TOTAL	71-87	82-94	55-77	50-69	38-43	-51	-34	-26	-54%

* Totals based on review and determination of records lying within the now defined SPA boundaries.

^ a further two possible pairs outside boundary

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6. Appendices

Appendix 1 Sex and age class of sightings of hen harriers during national surveys

Sex	2022	2015	2010	Change 2022-2015 (%)	Change 2022-2010 (%)
Male	1117	1123	943	-0.5	18.5
Female	620	1066	865	-71.9	-28.3
Immature male	37	120	50	-69.2	-26
Juvenile	98	378	110	-74.1	-10.9

Appendix 2 The range of threats and pressures observed by surveyors during 2022 within 500m of hen harrier suitable breeding habitats

Code	Description of activity, threat or pressure	500m (n)	%
B2	forest and plantation management & use	797	23.0
X	no threats or pressures	688	19.9
C2	mechanical removal of peat	247	7.1
D1	paths, tracks, cycling tracks (includes non-paved forest roads)	238	6.9
A6	non intensive grazing	171	4.9
C3	wind energy production	152	4.4
A2	agricultural intensification	141	4.1
G3	walking, horse-riding and non-motorised vehicles	141	4.1
A5	intensive grazing	132	3.8
B1	forest planting on open ground (increase in forest area, planting *e.g.* on grassland, heathland)	104	3.0
D2	roads, motorways (all paved/ tarred roads)	81	2.3
G2	outdoor sports and leisure activities, recreational activities	61	1.8
B3	forest replanting (*i.e.* replanting on forest ground after clear-cutting)	60	1.7
D3	utility and service lines (*e.g.* power-lines, pipelines)	57	1.6

Code	Description of activity, threat or pressure	500m (n)	%
B4	forest clearance (clear-cutting, removal of all trees)	56	1.6
G1	human intrusions and disturbances	53	1.5
C1	hand cutting of peat	46	1.3
G4	motorised vehicles	31	0.9
J3	uncontrolled burning (*e.g.* widespread unmanaged or malicious burning)	25	0.7
G5	off-road motorised driving	23	0.7
K1	interspecific faunal relations - predation (by other birds *e.g.* crows)	23	0.7
K2	interspecific faunal relations - predation (by mammals *e.g.* foxes)	19	0.5
B7	other forest activities (*e.g.* erosion due to forest clearing, fragmentation)	13	0.4
J7	anthropogenic reduction of habitat connectivity (*i.e.* fragmentation such as by removal of large areas of habitat or creation of barriers between habitats)	13	0.4
J5	reduction or loss of specific habitat features (*e.g.* removal of hedgerows, deep heather, scrub, walls, drains)	12	0.3
E2	dispersed habitation (*i.e.* little or no human disturbance)	9	0.3
A3	mowing / cutting of grassland	8	0.2
A9	removal of hedges and copses or scrub	7	0.2
B6	fertilisation (forestry)	7	0.2
D5	improved access to site	7	0.2
J4	modification of water levels or waterbodies	5	0.1
A1	modification of cultivation practices	4	0.1
A4	abandonment / lack of mowing	4	0.1
A7	abandonment of pastoral systems, lack of grazing	4	0.1
B5	thinning of tree layer	4	0.1
H1	pollution (*e.g.* water pollution, fly-tipping)	4	0.1
O	other threats or pressures not listed above	4	0.1
F2	illegal killing (*e.g.* shooting, trapping, poisoning)	3	0.1
A8	fertilisation (agricultural)	2	0.1
F1	nest destruction	2	0.1
G6	other outdoor sports and leisure activities	1	0.0

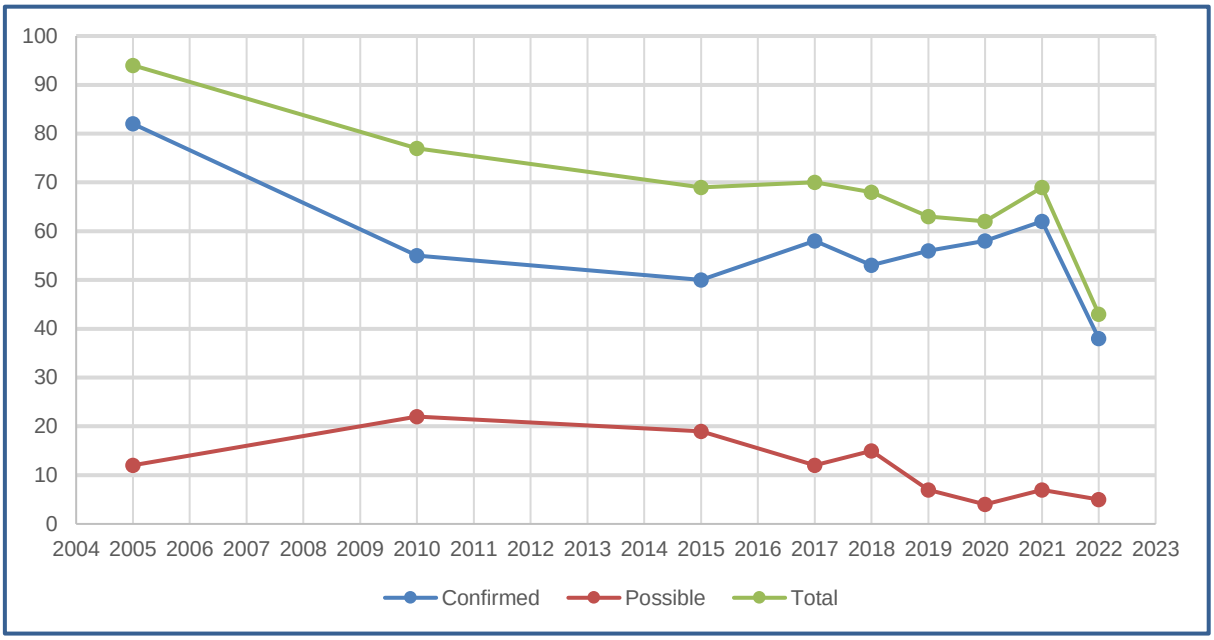
Code	Description of activity, threat or pressure	500m (n)	%
J1	natural fires	1	0.0
D4	aircrafts or flightpaths	0	0.0
E1	urbanisation, residential and commercial development	0	0.0
G7	military manoeuvres	0	0.0
J2	controlled burning (*e.g.* strip burning for grouse management)	0	0.0
J6	reduction of prey availability	0	0.0
		3460	100

Appendix 3. The range of threats and pressures observed by surveyors during 2022 within 2 km of hen harrier suitable breeding habitats

Code	Description of activity, threat or pressure	2 km (n)	%
B2	forest and plantation management & use	837	24.2
X	no threats or pressures	486	14.0
C3	wind energy production	305	8.8
C2	mechanical removal of peat	197	5.7
A2	agricultural intensification	188	5.4
D1	paths, tracks, cycling tracks (includes non-paved forest roads)	185	5.3
A6	non intensive grazing	137	4.0
A5	intensive grazing	126	3.6
B1	forest planting on open ground (increase in forest area, planting *e.g.* on grassland, heathland)	126	3.6
D2	roads, motorways (all paved/ tarred roads)	106	3.1
G3	walking, horse-riding and non-motorised vehicles	100	2.9
B4	forest clearance (clear-cutting, removal of all trees)	86	2.5
B3	forest replanting (*i.e.* replanting on forest ground after clear-cutting)	76	2.2
D3	utility and service lines (*e.g.* power-lines, pipelines)	66	1.9
J3	uncontrolled burning (*e.g.* widespread unmanaged or malicious burning)	55	1.6
G4	motorised vehicles	49	1.4
G1	human intrusions and disturbances	44	1.3
G2	outdoor sports and leisure activities, recreational activities	42	1.2
C1	hand cutting of peat	37	1.1
G5	off-road motorised driving	21	0.6
E1	urbanisation, residential and commercial development	17	0.5
K1	interspecific faunal relations - predation (by other birds *e.g.* crows)	17	0.5
E2	dispersed habitation (*i.e.* little or no human disturbance)	16	0.5
K2	interspecific faunal relations - predation (by mammals *e.g.* foxes)	15	0.4
B6	fertilisation (forestry)	14	0.4
A3	mowing / cutting of grassland	13	0.4

Code	Description of activity, threat or pressure	2 km (n)	%
B7	other forest activities (*e.g.* erosion due to forest clearing, fragmentation)	13	0.4
A9	removal of hedges and copses or scrub	12	0.3
O	other threats or pressures not listed above	12	0.3
A7	abandonment of pastoral systems, lack of grazing	7	0.2
A8	fertilisation (agricultural)	7	0.2
J5	reduction or loss of specific habitat features (*e.g.* removal of hedgerows, deep heather, scrub, walls, drains)	7	0.2
J7	anthropogenic reduction of habitat connectivity (*i.e.* fragmentation such as by removal of large areas of habitat or creation of barriers between habitats)	7	0.2
A1	modification of cultivation practices	6	0.2
D4	aircrafts or flightpaths	5	0.1
B5	thinning of tree layer	4	0.1
D5	improved access to site	4	0.1
G6	other outdoor sports and leisure activities	3	0.1
G7	military manoeuvres	3	0.1
J2	controlled burning (*e.g.* strip burning for grouse management)	3	0.1
H1	pollution (*e.g.* water pollution, fly-tipping)	2	0.1
J6	reduction of prey availability	2	0.1
F1	nest destruction	1	0.0
F2	illegal killing (*e.g.* shooting, trapping, poisoning)	1	0.0
A4	abandonment / lack of mowing	0	0.0
J1	natural fires	0	0.0
J4	modification of water levels or waterbodies	0	0.0
		3460	100

Appendix 4 Hen harrier SPA population trends between 2005 and 2022



Appendix 5 Indicative hen harrier population modelling 2022

Region	Year	Confirmed pairs	Possible pairs	Total adults	Adult survival	Live adults	Dead adults	Mean young/ breeding pair	Juveniles fledged	Survival rate	Surviving young	Surplus / Deficit
Stack's to Mullaghareirk Mountain, West Limerick Hills & Mount Eagle	2022	21	0	42	0.778	32.676	9.324	0.95	20	0.361	7.220	-2.10
Mullaghanish to Musheramore Mountains	2022	1	0	2	0.778	1.556	0.444	0.00	0	0.361	0.000	-0.44
Slievefelim to Silvermines Mountains	2022	3	1	8	0.778	6.224	1.776	0.25	1	0.361	0.361	-1.42
Slieve Bloom Mountains	2022	8	1	18	0.778	14.004	3.996	0.67	6	0.361	2.166	-1.83
Slieve Aughty Mountains	2022	3	2	10	0.778	7.78	2.220	0.80	4	0.361	1.444	-0.78
Slieve Beagh	2022	2	1	6	0.778	4.668	1.332	0.00	0	0.361	0.000	-1.33
Inside SPAs	2022	38	5	86	0.778	66.908	19.092	0.72	31	0.361	11.191	-7.90
Outside SPAs	2022	47	16	124	0.778	98.028	27.972	0.76	44	0.361	15.884	-12.09
Whole population	2022	85	21	210	0.778	164.936	47.064	0.74	75	0.361	27.075	-19.99

Appendix 6 Hen harrier survey squares prioritisation matrix, coverage and suitability review

Square Colour	Definition	Priority	No. Squares	Not Suitable	No. Allocated	% Coverage	Not suitable	No. Surveyed	% Surveyed	Data not received
	green' squares where breeding had been confirmed (see Barton *et al*., 2006; Ruddock *et al*., 2012; Balmer *et al*., 2013; Ruddock *et al*., 2016) in the period 1998 – 2021	1	105	7	101	96	7	100	95	3
	'yellow' squares where breeding had been recorded as possible (see Barton *et al*., 2006; Ruddock *et al*., 2012; Ruddock *et al*., 2016) in the period 1998 – 2021	2	28	2	26	93	2	24	86	2
	'orange' squares in which hen harrier had been sighted in the period 1998 – 2021 and/or where suitable habitat was recorded	3	129	48	101	78	48	93	72	25
	'red' squares which had no historical hen harrier sightings, but which contained known or potentially suitable breeding habitat	4	65	15	44	68	10	41	63	3
	pink' squares where no square was allocated but survey effort was undertaken, and results submitted by surveyors	-	13	0	0	0	0	13	100	0

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