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Hen Harrier *Circus cyaneus* ecology and conservation during the non-breeding season in Ireland

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ABSTRACT

Capsule: A total of 203 Hen Harrier *Circus cyaneus* winter roosts was recorded in Ireland between 2004 and 2020. The main habitat used for roosting was heath/bog. Burning and land-use change including forestry, agriculture and renewable energy were the most frequent among various pressures and threats recorded.

Aims: To find and survey Hen Harrier roosts and establish the distribution and habitat associations during the non-breeding season, as well as the conservation issues facing the species during that time.

Methods: Surveys were undertaken across Ireland each winter from 2004 to 2020, searching for roosts and recording occupancy, behaviour, roost characteristics, pressures and threats. Satellite tracking was also used to locate roosts.

Results: A total of 203 roosts was recorded, with a widespread distribution. Heath/bog was the most frequently used habitat (53% of roosts), while 53% of roosts were located at less than 100 m above sea level. More than half (52%) of the roosts were communal. The median number of Hen Harriers per roost was 2, the average number was 2.5 and the maximum recorded was 16. Almost a third (31%) of sites documented by this long-term study have become inactive due to anthropogenic pressures. Primary pressures and threats included the disturbance/removal of roosts (e.g. through burning and wind farm development) and changes to the surrounding landscape (e.g. agricultural intensification and afforestation).

Conclusion: Identifying the distribution, roosts and habitat use of Hen Harriers during the non-breeding season, as well as the prevalent threats and pressures, provides a solid platform on which to base necessary conservation action in Ireland. Supporting landowners to maintain or improve habitats, and taking account of roosts and hunting grounds in assessing proposed developments/land-use change should be considered in any conservation strategy for Hen Harriers.

ARTICLE HISTORY

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The Hen Harrier *Circus cyaneus* is a native Irish bird of prey listed on Annex I of the Birds Directive (Directive 2009/147/EC). The species has undergone a population decline in Ireland since the 1970s, when there were an estimated 300 breeding pairs (Watson 1977) and when Hen Harriers were found 'with ease' (O'Flynn 1983). Today, it is one of Ireland's rarest birds, with between 154 and 209 breeding pairs across 18 counties on the entire island (Ruddock *et al.* 2016, Wotton *et al.* 2018). Ruddock *et al.* (2016) recorded a 34% decline between 2000 and 2015 in the Republic of Ireland. Given this decline, the Hen Harrier is the subject of conservation concern (Colhoun & Cummins 2013, Eaton *et al.* 2015). There have been several breeding surveys for the Republic of Ireland and Northern Ireland since the turn of the century (Sim *et al.* 2001, Sim *et al.* 2007, Norriss *et al.* 2002, Barton *et al.* 2006,

Ruddock *et al.* 2012, Ruddock *et al.* 2016, Hayhow *et al.* 2013, Wotton *et al.* 2018) and a significant amount of research on Hen Harrier breeding ecology in the region (Scott *et al.* 1991, Scott *et al.* 1993, Scott & Clarke 2007, O'Donoghue 2010, 2012, Wilson *et al.* 2012, Caravaggi *et al.* 2019a, Caravaggi *et al.* 2019b, Caravaggi *et al.* 2020, Sheridan *et al.* 2020). The distribution of Hen Harriers in Ireland and factors affecting the breeding population are consequently well understood, with forestry, food availability, recreation, predation, burning and loss of habitat features being the main pressures (Ruddock *et al.* 2016, Wotton *et al.* 2018). A suite of eight breeding Special Protection Areas (SPAs) were designated in 2007, six in the Republic of Ireland and two in Northern Ireland. The National Parks & Wildlife Service initiated a Hen Harrier Threat Response Plan

in 2013 'to cease, avoid, reduce or prevent threats, pressures or hazards that may be having an adverse effect on the conservation status'. While the breeding season is of obvious importance, the period outside of the breeding season (mid-July to mid-March) effectively accounts for three-quarters of the year and was first identified by O'Donoghue (2010) as a limiting factor in Irish population dynamics, with fewer juveniles surviving each winter than would be required to maintain a stable population. For all species, the period outside of the breeding season is of integral importance to population dynamics and when considered with the breeding season, allows a more balanced and complete view of ecological and conservation requirements.

However, there is a dearth of published information in relation to Hen Harriers in Ireland outside of the breeding season. Clarke & Watson (1990) reported a total of ten roost sites from Ireland in records collated during the winter of 1983/84. By the turn of the century, the locations of these roosts were no longer known and the lack of knowledge on wintering Hen Harriers was a concern, particularly in the context of a declining population impacted by various pressures (O'Donoghue *et al.* 2011, Ruddock *et al.* 2016, Caravaggi *et al.* 2019a). To address these issues, the present study, undertaken between 2004 and 2020, set out to (a) investigate the distribution of Hen Harriers outside of the breeding season; (b) identify and record roost locations; (c) record the attendance at roosts (including ratio of ringtails to grey males); (d) observe and record behaviour at roosts (including associations with other species); (e) examine Hen Harrier habitat associations during the non-breeding period; (f) identify and record the pressures and threats to these sites and (g) consider what protection, if any, is afforded to these roost sites. By satisfying the objectives of the study and presenting information on an otherwise understudied aspect of the Hen Harrier's ecology, steps can be taken towards conservation measures for the entire lifecycle of the species.

During this period, Natural England, the Royal Society for the Protection of Birds (RSPB) and the Hawk & Owl Trust have all engaged in the satellite tracking of Hen Harriers. Satellite tracking studies can provide insights into different aspects of raptor migration and habitat use outside of the breeding season (Robinson *et al.* 2010, López-López 2016, McKinnon & Love 2018). Citizen science has proven valuable and successful in ecological studies and conservation policies, advancing our knowledge of various habitats and species, including threatened bird species, through the collation of large amounts of data

on large spatial and temporal scales (Baral & Poudyal 2020, Wijewardhana *et al.* 2020). Here, I present findings from this long-running study, which is a combination of the citizen science based Irish Hen Harrier Winter Survey (IHHWS) and the satellite tracking information provided by the aforementioned organizations.

Methods

Most of the data on Hen Harrier non-breeding distribution and roost locations were generated through citizen science. A combination of sightings reports and dedicated watches was further supplemented by satellite tag data, while roost site attribute investigations were undertaken by both the contributors and myself as survey coordinator. For roost sites where IHHWS participants had carried out local breeding season surveys, I found out from them whether a Hen Harrier breeding attempt had been made within 500 m of the roost site since the start of the IHHWS in 2004.

Casual sightings

A public awareness campaign was organized at various levels through national, local and online media, including press, radio, internet, social media and public presentations, to encourage people to record and report sightings of Hen Harriers between mid-July and mid-March from 2004 to 2020. Casual sightings were instrumental in guiding search effort for Hen Harrier roosts; for example, concentrations of casual sightings in a particular area might suggest a nearby roost, while a harrier seen travelling in a particular direction at dusk might prompt a search for a roost in the area it was flying towards.

Dedicated non-breeding surveys

Non-breeding surveys aimed to find previously unknown roosts and to undertake watches at these roosts thereafter. Guidelines (O'Donoghue 2019) and mentoring were provided to a total of 310 surveyors who undertook such surveys for Hen Harriers over 16 winters from 2004/5–20019/20. A total of at least 6,714 dawn or dusk watches were conducted at 723 (occupied and unoccupied) sites. The distribution of this search effort is summarized in Figure 1, while the number of seasons during which roost watches were undertaken is summarized in Figure 2. All surveyors were requested to maintain a maximum level of

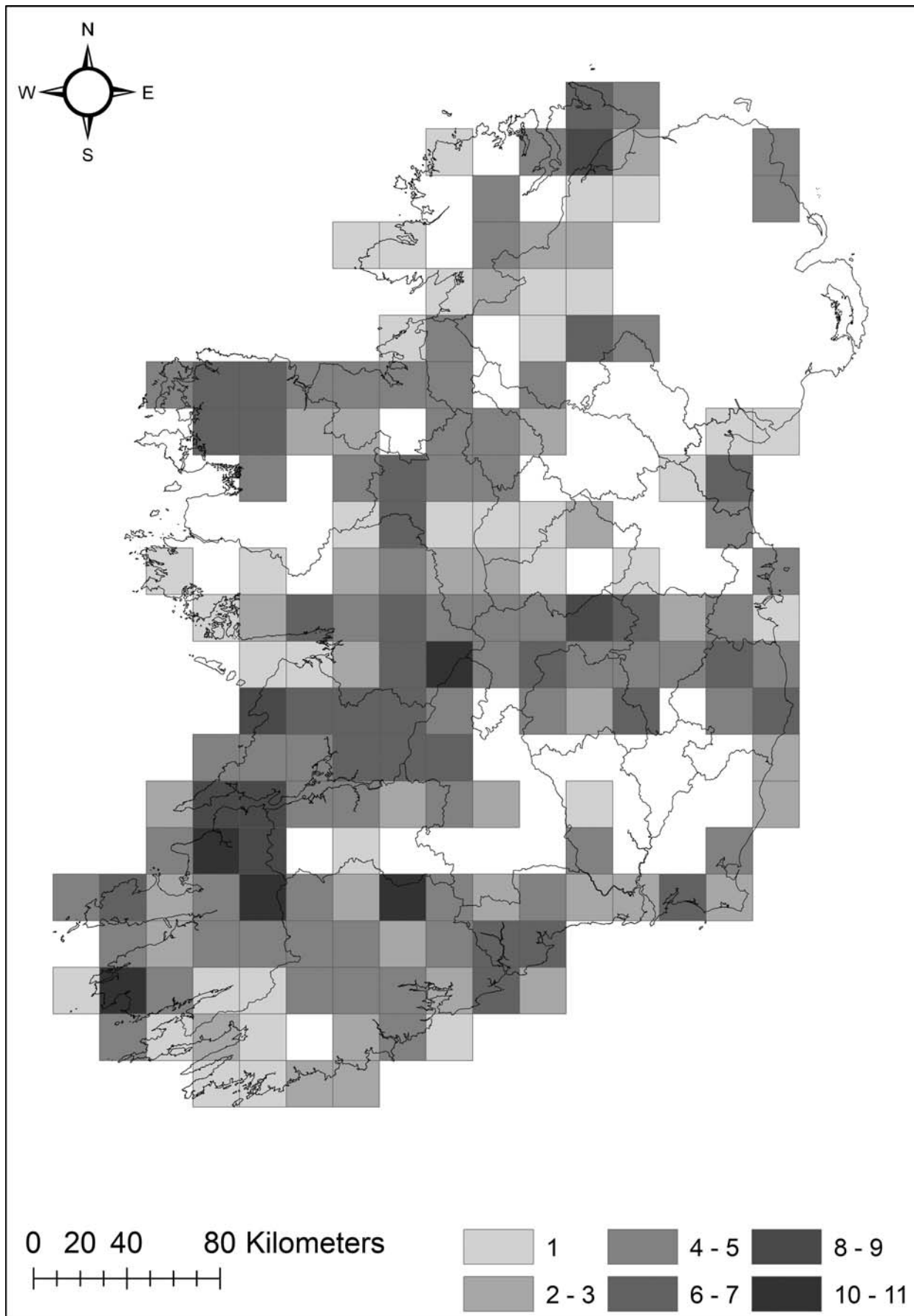


Figure 1. The distribution and number of potential sites surveyed per 20 km square between 2004 and 2020.



Figure 2. Survey effort in terms of number of seasons during which roost watches have been conducted in each 20 km square between 2004 and 2020.

confidentiality regarding roost locations, to remain inconspicuous and to not disturb any birds.

Finding roosts

A combination of remote-sensing, site-specific knowledge, information from casual sightings and discussion with surveyors was used to guide surveyors across 27 counties to sites that were deemed potentially suitable for roosting harriers. Characteristic features in this regard were derived from Clarke & Watson (1990) and so the habitat types targeted for surveys included heath/bog, plantation forests that had not reached thicket stage, scrub, grassland, crops, dunes, marshes and reedbeds. The number and availability of surveyors determined the extent to which sites could be checked and rechecked. In most cases, if a roost was not found at a site on the first attempt, another suitable site would be checked, rather than checking the same site again.

Data from six satellite-tracked birds, tagged in Scotland in 2013, 2016, 2017 and 2018 (two birds) and Isle of Man in 2019, indicated non-breeding roosting locations of these birds while in Ireland (in the winters of 2013/14, 2016/17, 2017/18, 2018/19 and 2019/20). The satellite tags were manufactured by Microwave Telemetry and transmitted data via the Argos satellite. Only the highest accuracy class data (LC3 data, accurate to <250 m) transmitted during darkness hours were used to confirm roost locations. These locations were visited for ground-truthing and roost watches were undertaken where possible.

Roost watches

Roost watches were undertaken in the morning from first light until 30 min after sunrise and in the evening from 40 min before sunset until darkness. The longest any surveyor stayed watching a roost after sunrise was 90 min, while the earliest evening watch was started 120 min before sunrise. The mean duration of a watch was 61 min. Roost watches were carried out only when weather conditions did not compromise observations. While there was variation in survey effort between sites and years, coordinated surveys at known roosts were scheduled for the first weekend of each of the six months between October and March.

Through personal observations prior to the initiation of the survey, it was known that Hen Harriers can alight on the ground, apparently going to roost but rising before settling again, or may leave the immediate roost site and return again. Observers were cautioned to be aware of this and provided with guidance to

avoid counting the same individual multiple times. Data from observations were recorded on standardized sheets (or submitted online at www.ihhws.ie), with the number of birds at roost, time and direction of arrival/departure, behaviour, intra-specific and inter-specific interactions and time of settling/rising recorded. Other raptors and bird species of conservation importance were also recorded. Data on submitted forms were entered into the Irish Hen Harrier Winter Survey (IHHWS) database. For the purpose of this study, Hen Harriers were distinguished as either 'grey males' (2nd winter males and older) or 'ringtails' (females or juveniles of either sex), as complete accuracy in distinguishing juveniles from adult females cannot be guaranteed, particularly at times of fading light during roost watches (Clarke & Watson 1997, Clarke *et al.* 1997).

Detailing roost site attributes

A roost was considered to be a site where at least one Hen Harrier was recorded to roost for at least one night during the non-breeding season. Roost sites were distinguished from other roost sites in their geographical area, where they were not part of one contiguous area of habitat. The following attributes were recorded for roost sites: location, habitat, land-use, pressures and threats, ownership, access details and vantage point locations. While Hen Harriers selected various micro-habitat features within roosts, for the purpose of this study broad habitat categories were assigned to individual roosts. These were assigned based on data provided by observers, remote sensing (utilizing the most recent open-source orthoimagery from Ordnance Survey Ireland at <http://map.geohive.ie/> and Ordnance Survey of Northern Ireland at <https://apps.d.aera-ni.gov.uk/nedmapviewer/>) and ground-truthing. Ownership was categorized through the local knowledge of fieldworkers as private (individual ownership), commonage (land owned and managed 'in common' by multiple shareholders), semi-state or state.

The types of roosts, their regularity of use and status were classified according to Table 1. Depending on their occupancy, roosts were categorized as communal (where more than one Hen Harrier was recorded during a watch) or solitary, and categorized as regular (where the sites were occupied during more than 50% of watches) or sporadic (where the sites were occupied during less than 50% of watches). Roosts were classified as intact (roost site and surrounding lands still suitable for Hen Harriers), vulnerable (still in use but with significant pressures exerted on the roost or

Table 1. Classification of Hen Harrier roost types, regularity of use and status.

Variable	Category	Description
Roost type	Communal	Two or more individual birds recorded roosting
	Solitary	No more than one individual bird recorded roosting
Regularity of use	Regular	The roost was occupied the majority of times it was watched
	Sporadic	The roost was unoccupied the majority of times it was watched
Status	Intact	In use, roost and surrounding lands remain suitable
	Vulnerable	In use but with significant pressures exerted on the roost or surrounding landscape
	Lost	The birds and/or roost habitat are no longer present

surrounding landscape) or lost (the birds and/or habitat no longer present).

Pressures on and threats to roost sites and the ability of the local landscape to sustain Hen Harriers were recorded, following O'Donoghue *et al.* (2011), Ruddock *et al.* (2016) and Caravaggi *et al.* (2019a) and using the 2018 European Union standard list of impact codes (DG Environment 2018). While acknowledging the differences between pressures (any activity, management or action presently impacting) and threats (any activity, management or action likely to impact), because of the extensive overlap between factors that can act as threats and pressures I hereafter mainly use the term 'pressures' to refer to factors that can negatively influence Hen Harriers and roosts in either way. Pressures on roost sites were considered to apply within 750 m of the roost, following Ruddock & Whitfield (2007), while issues for the surrounding landscape were considered to apply within 9 km of the roost, following Arroyo *et al.* (2014). Pressure categories included both anthropogenic sources (e.g. vegetation burning, infrastructure, agriculture, land-use change, peat extraction, drainage and disturbance) and natural sources (e.g. habitat succession, interspecific relations, flooding and invasive alien species). Open-source data (available at the same links provided earlier) were used to determine whether the roosts were located within any nature conservation areas, including Special Areas of Conservation (SACs), SPAs, Natural Heritage Areas (NHAs), Areas of Special Scientific Interest (ASSIs), proposed Natural Heritage Areas, Areas of Outstanding Natural Beauty, Ramsar, Nature Reserve, etc.

As the Hen Harrier is a species of conservation concern and subject to persecution and disturbance pressures in Ireland (O'Donoghue *et al.* 2020), roost locations are presented in a manner in which they cannot be specifically identified. ArcGIS Pro was used

to generate a 20 km square 'grid' vector shapefile. This vector file and an Irish counties vector file were each overlaid to create a map of Ireland, showing the number of roosts 'within' each 20 km square. The same approach was applied to displaying survey effort.

Results

New roosts recorded

Through on-site surveys and satellite data, a total of 203 roosts were recorded across 27 counties. Figure 3 presents the number of roosts recorded at a 20 km grid square level. Of the 174 roost sites where breeding season survey information was available, 41 (24%) had breeding attempts within 500 m since 2004. Of these, a total of 41 roost sites (24%) had a breeding attempt within 500 m. Volunteers located 158 (78%) of the roosts, while data generated by the satellite tags revealed the locations of the remaining 45 roosts. The satellite tracking data showed individual birds used more than one roost during the course of the non-breeding season, but those that survived to mid-winter established home ranges with consistently occupied roosting grounds. A total of 83 roosts (41% of all roosts recorded) were in the three counties of Kerry ($n = 32$), Cork ($n = 30$) and Clare ($n = 21$). Roosts were found between 0 and 560 m above sea level. Just over half (53%) of the roosts were located below 100 m above sea level. A breakdown of elevation categories is provided in Figure 4.

Attendance at roosts

Of the 203 roosts recorded, 105 were classed as communal and 98 as solitary. Of the communal roosts, almost half (48%, $n = 50$) hosted a maximum of two birds during any single watch, while just 10% of communal roosts were recorded to hold more than 7 birds during any single watch. The maximum number of birds recorded at a roost during any single watch was 16. Figure 5 summarizes the peak numbers recorded at individual roost sites (in a single watch). Figure 6 summarizes the average annual peak number recorded at all roosts within each 20 km square. Of all the birds recorded at winter roosts during the 16 years of survey effort, 41% were grey males and 59% were ringtails.

Times of arrival and departure

Times of arrival and departure to and from roosts are summarized in Figure 7. Hen Harriers arrived to roost

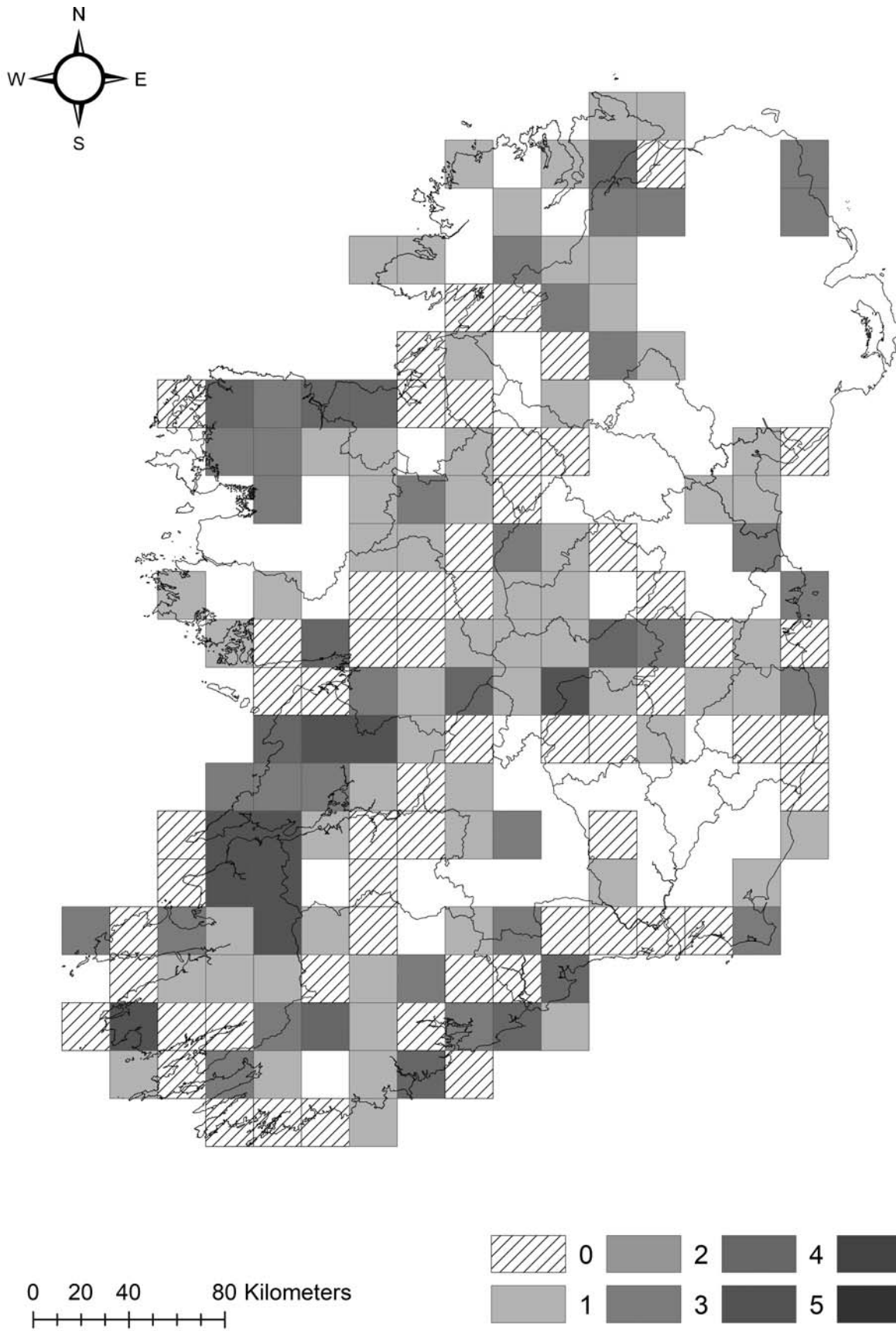


Figure 3. The distribution and number of Hen Harrier non-breeding roosts recorded per 20 km square between 2004 and 2020. Hatched squares represent 20 km squares in which surveys were conducted but where no roosts were found.

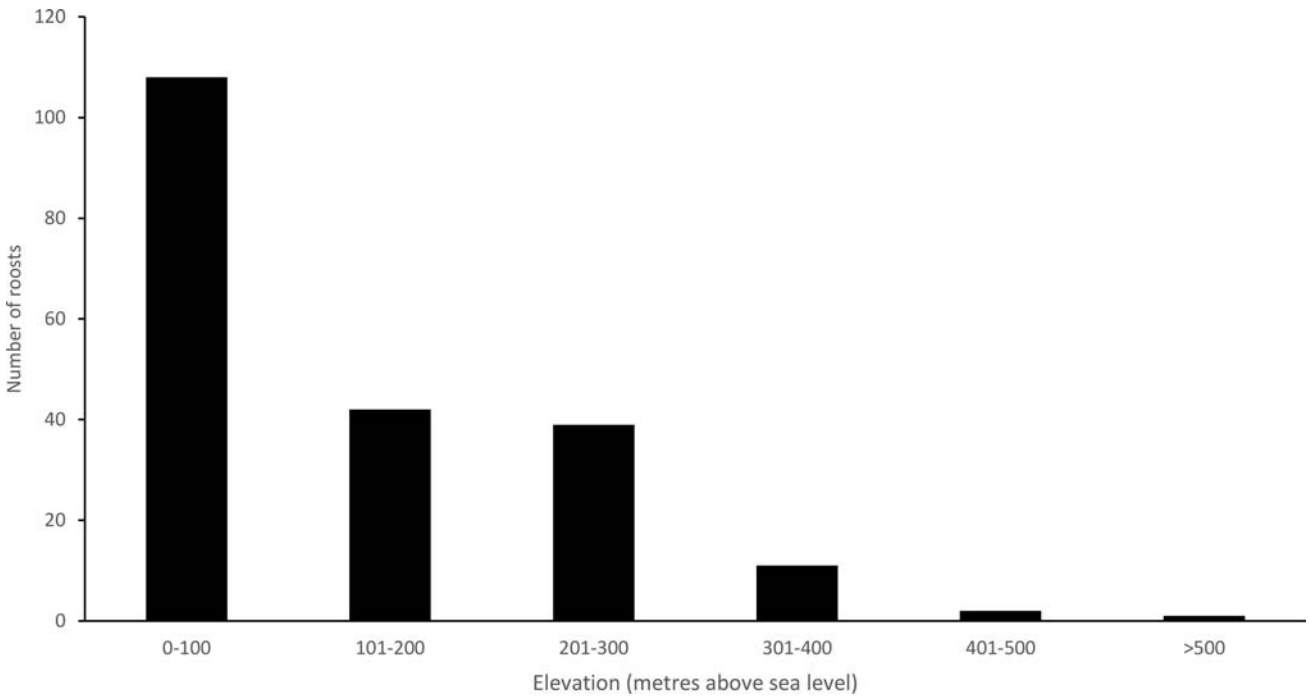


Figure 4. Elevation of roosts used by Hen Harriers during the non-breeding season in Ireland.

from as early as 88 min before sunset. The peak time for harriers returning to roost occurred three to four minutes before sunset, but continued until as late as 40 min after sunset, in virtual darkness. In the morning, all observed departures of harriers from roosts took place before sunrise, from as early as 44 min before sunrise to just five minutes before sunrise. Data from casual sightings showed Hen Harriers also

frequented roost sites at various other times of the day (beyond morning and evening times).

Behaviour at roosts

Behavioural observations showed Hen Harriers scouted around their roost site prior to settling for the evening, sometimes perching and preening, sometimes

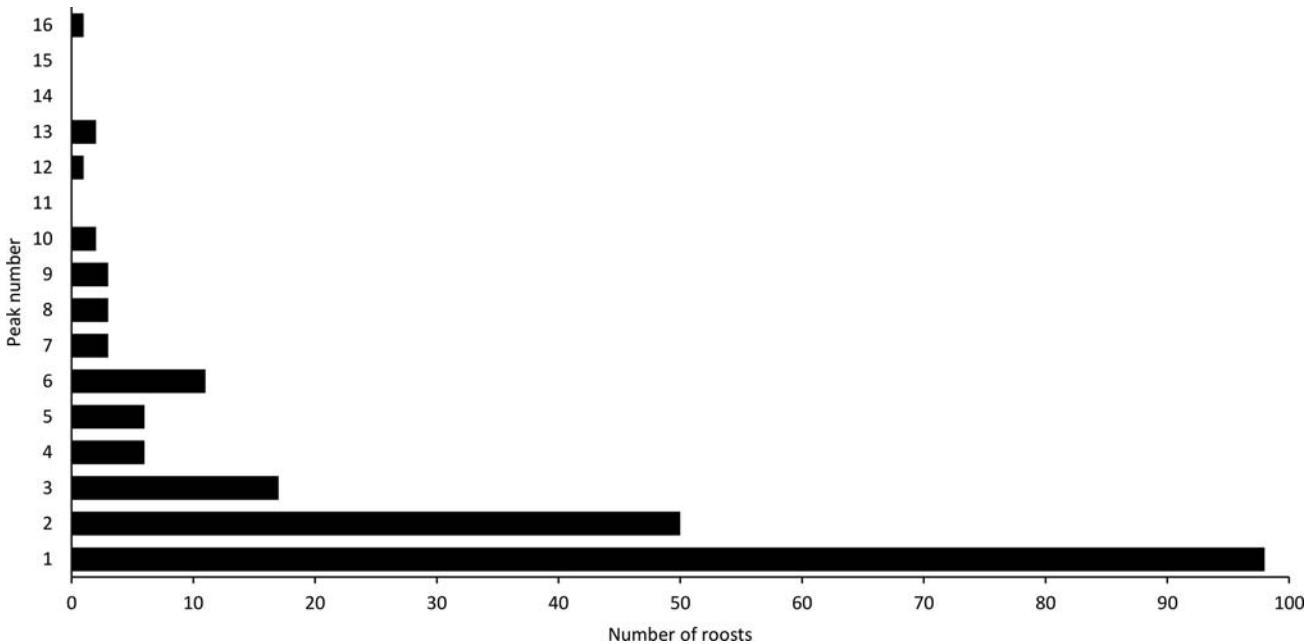


Figure 5. Peak counts at Hen Harrier non-breeding roosts in Ireland.

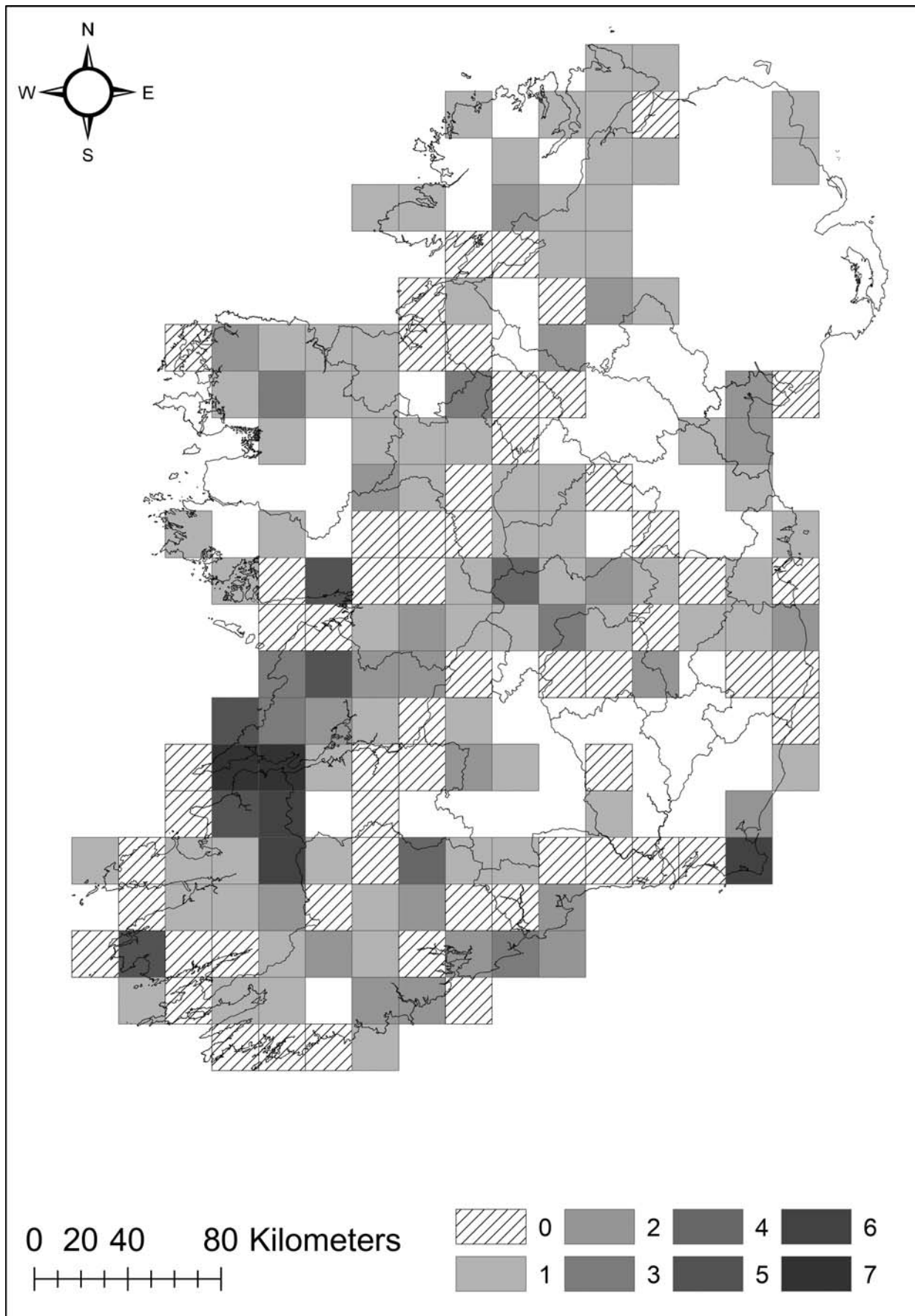


Figure 6. The average annual maximum number of Hen Harriers recorded at non-breeding roosts in each 20 km square between 2004 and 2020.

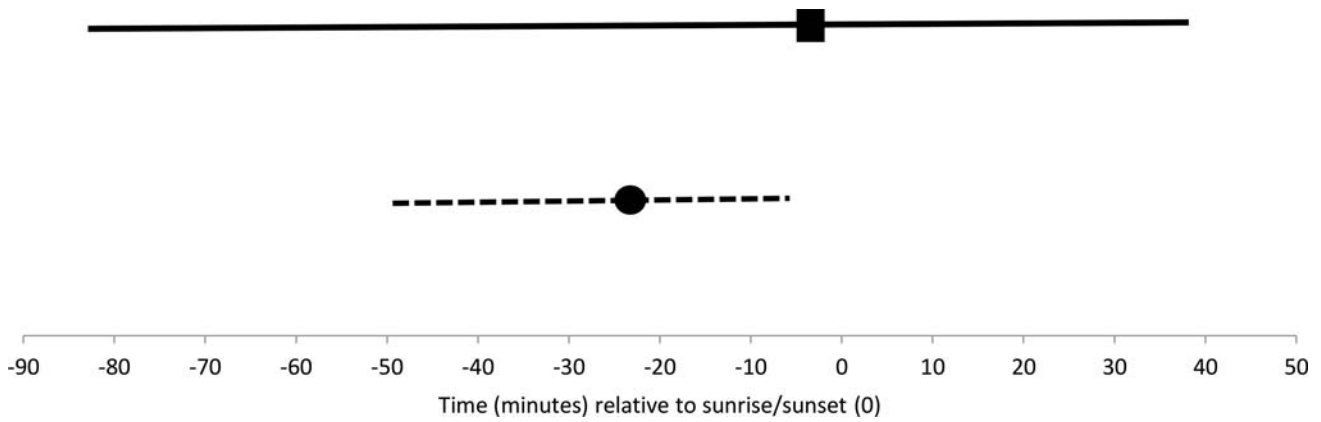


Figure 7. Times of arrival to (solid line) and departure from (dashed line) non-breeding Hen Harrier roosts. Data are summarized from 16 seasons. The square denotes mean arrival time, the circle denotes mean departure time and bars indicate the range.

interacting with other harriers or other species. While harriers frequented roosts in all weather conditions surveyed, they appeared to spend more time flying around and over roosts during dry, breezy conditions (Beaufort Force 3-5). In 11% of watches where communal roosting was recorded, Hen Harriers arrived at roosts or departed from roosts in pairs. The most frequently recorded interaction with other species (accounting for 23% of such interactions) was with Hooded Crows *Corvus cornix*, which would actively mob Hen Harriers.

A shared space

Another raptor species was recorded at every roost site that was surveyed more than once ($n = 119$). Of these

roost sites, 63% had at least two other raptor species, 22% had at least three other raptor species, 9% had at least four other raptor species, 5% had at least five other raptor species and 1% had at least six other raptor species. All other species of native Irish raptor were recorded at the Hen Harrier winter roosts, the most commonly associated being European Sparrowhawk *Accipiter nisus* (at 51% of roosts), Common Kestrel *Falco tinnunculus* (at 50% of roosts), Short-eared Owl *Asio otus* (at 22% of roosts), Merlin *Falco columbarius* (at 15% of roosts) and Barn Owl *Tyto alba* (at 7% of roosts). While the other species were primarily hunting or travelling through the roost sites, Short-eared Owls were recorded roosting at each of the 45 sites where they were recorded. Some notable vagrants including Northern Harrier *Circus*

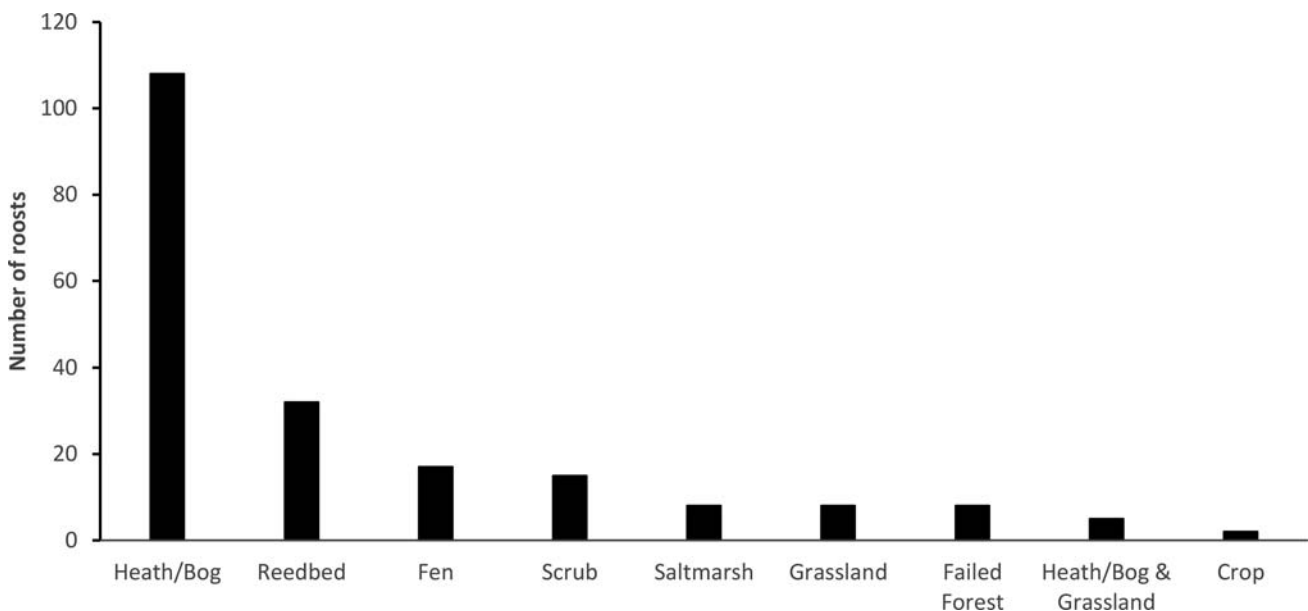


Figure 8. Primary habitat at roosts used by Hen Harriers during the non-breeding season in Ireland.

hudsonius, Pallid Harrier *Circus macrourus*, Montagu's Harrier *Circus pygargus*, and Osprey *Pandion haliaetus* were also recorded at particular roost sites.

Roosting habitats

Roost sites ranged in size from hundreds of square metres to kilometres squared. The most frequently used broad habitat category for roosting was heath/bog ($n = 108$), followed by reedbed ($n = 32$). The other broad habitat categories in which Hen Harriers were found to roost in Ireland included fen ($n = 17$), scrub ($n = 15$), saltmarsh ($n = 8$), grassland ($n = 8$), forests that had not reached thicket stage, specifically 'failed forest' i.e. plantations with stunted growth ($n = 8$), heath/bog and grassland ($n = 5$) and crop ($n = 2$). The combined habitat category of heath/bog and grassland was applied to individual roosts where Hen Harriers used both of these individual broad habitat categories. Figure 8 summarizes the relative frequency of each broad habitat category.

Classification of roosts

A total of 74 roosts were considered to be frequented regularly (i.e. occupied on more than 50% of watches), while 45 roosts were classed as 'sporadic'. There was insufficient data for the remaining 84 sites, which generally would have been watched once only, or located by way of satellite tag data. Of 119 roost sites for which a status could be definitively attributed, 82 were classed as intact, 20 as vulnerable and 17 as lost; 12 of which were communal roosts that were lost during the period of this study.

Pressures and threats

Certain pressures on, and threats to, Hen Harriers during the non-breeding season were considered ubiquitous. These included reduced and fragmented habitat/food availability in the wider landscape, natural predation, human persecution and climate change. Specific information on threats and pressures was recorded for 190 of the 203 roosts (data were not discernible for thirteen of the roosts). The main pressures identified and their frequencies (across the 190 roosts) are summarized in Table 2. Just four (2%) roost sites were perceived to not have any site-specific pressures. The most common pressure recorded at the roosts was vegetation burning, associated with 46% of roosts. The next most common pressures identified were those of renewable energy developments and associated infrastructure (transmission lines). At least

Table 2. Site-specific pressures recorded at 190 Hen Harrier roosts in Ireland.

Pressure	Roosts	% Roosts
Burning	88	46
Renewable energy development, including infrastructure	83	44
Transmission of electricity and communications (cables)	76	40
'Other' agriculture activities	67	35
Natural succession resulting in species composition change	64	34
Interspecific relations (competition, predation, parasitism, pathogens)	61	32
Conversion to forest from other land-uses, or afforestation	59	31
Peat extraction	45	24
Flooding (natural processes)	42	22
Intensive grazing or overgrazing by livestock	36	19
Sports, tourism and leisure activities	29	15
Other human intrusions and disturbance (e.g. illegal dumping).	27	14
Drainage	26	14
Roads, paths, railroads and related infrastructure (e.g. bridges, viaducts, tunnels)	20	11
Application of synthetic fertilizers in forestry, including liming of forest soils	15	8
Land, water and air transport activities generating noise, light and other forms of pollution	14	7
Invasive alien species	13	7
Creation or development of sports, tourism and leisure infrastructure (outside the urban or recreational areas)	7	4
Harvesting of crops and cutting of croplands	5	3
Solar power, including infrastructure	2	1

one site was lost when pylons for a new electricity transmission line were constructed in the roost. The processes of habitat succession and interspecific competition were identified at 34% and 32% of roosts respectively. Conversion to forestry was identified as a threat or pressure at 31% of roost sites. Changes to the landscape surrounding roosts that might affect its ability to support harriers included afforestation, intensification and homogenization of the agricultural landscape, land burning and clearance of scrub, the demise of the sugar beet industry, reductions in the area of spring-sown cereals, modern precision machinery resulting in less available grain for prey species and an increase in renewable energy developments. It is also important to recognize the general decline in biodiversity across the Irish landscape (DCHG 2017), which in turn would impact predators such as the Hen Harrier.

Of the 17 roosts classed as lost, 12 were used communally in multiple years prior to being lost. Five were lost due to agricultural intensification or other agricultural activities, five were planted with non-native conifers, three were impacted by persecution, two became unoccupied after Common Buzzards *Buteo buteo* colonized the roost, one site was excavated and one was lost due to a pylon for

powerlines being constructed. Four of the sites that were lost were in state/semi-state ownership, two of which were lost due to changes associated with agriculture in the immediate area surrounding the roost and two of which were sites lost directly to forestry.

Protection status of the roost sites

In terms of protection status, 120 (59%) of the 203 roosts had no statutory protection under the environmental legislation of Ireland or Northern Ireland and 106 roosts (52%) had no protection of any kind. Some 14 roosts existed within protection areas such as proposed Natural Heritage Areas or Areas of Outstanding Natural Beauty. A total of 83 sites existed within a Statutory protection area such as a Special Area of Conservation, SPA, Natural Heritage Area or Area of Special Scientific Interest. A total of 21 roosts existed within Hen Harrier breeding SPAs, while 3 roosts had been designated as SPAs with wintering Hen Harrier listed as a Special Conservation Interest. No habitats or landscapes surrounding roost sites had been designated for protection of non-breeding harriers. At least 38 (19%) of the 203 roosts were in state or semi-state ownership. The other 165 roosts were primarily in private ownership ($n = 105$), with some held in commonage ($n = 60$). It was clear that no land management (e.g. farming or forestry) had happened for a number of years for some roosts.

Discussion

A hitherto under-studied aspect of the ecology of the Hen Harrier in Ireland has now been examined in detail over a period of 16 years across a wide area. This has resulted in a better understanding of this important period, with regard to roost locations and distribution, numbers attending roosts, behaviour, habitat associations, pressures and conservation issues. Given that the non-breeding season accounts for three-quarters of the annual cycle of the Hen Harrier, and is a limiting factor in terms of population dynamics, this is vitally important if Ireland is to strive towards a meaningful and holistic conservation of the species.

While there is much overlap between the breeding and non-breeding distributions of the Hen Harrier in Ireland and a number of roost sites are also breeding sites and likely 'stepping stones' between winter and summer sites, the non-breeding distribution has been found to be more dispersed and to encompass a wider array of landscapes and habitats. The distribution outlined in this paper may not be the entire non-

breeding distribution of Hen Harriers in Ireland. For example, no roosts were found in County Leitrim, but there have been casual sightings of harriers there each winter that suggest there are likely to be roosts in the county. The percentage of roosts that were found in Counties Kerry, Cork and Clare (41%), was similar to the percentage of Irish breeding sites found in those counties (Ruddock *et al.* 2016). This may, at least in part, be due to the relatively high survey effort in those counties. The IHHWS has, to date, had a greater presence in the Republic of Ireland than in Northern Ireland. Increasing support and collaboration for surveys in Northern Ireland will be a priority for the future. It will also be important to maintain links with counterparts in Britain, given the degree of movement between and within both islands, and that a British-Irish metapopulation is very likely to exist.

The fact that over a third of known roosts were occupied on less than 50% of watches suggests that some sites could have been overlooked as roosts, had no harriers been found on the first watch (i.e. absence of birds on one watch did not necessarily mean the site was not a roost). This is an important consideration for surveys and investigations to inform planning and land-use change decisions. It also points to an important knowledge gap regarding how Hen Harriers use the landscape and individual roost sites during the non-breeding season, an aspect upon which more light has been shed in recent years thanks to satellite tracking of individual birds.

The fact that 45 roosts were found over the course of five winters through the movements of six satellite-tracked Hen Harriers, with only four already-known roosts visited by these birds, suggests that more roosts remain to be found. While individual satellite-tracked birds used more than one roost during the non-breeding season, this should not be taken to mean that Hen Harriers use sites transiently. Satellite tracking data has shown that individual Hen Harriers may return to the same roost sites on a multi-annual basis or use different roosts in different years (Hawk & Owl Trust unpublished data, Natural England unpublished data, O'Donoghue unpublished data, RSPB unpublished data), perhaps dependent on site-specific circumstances or other factors yet to be confirmed. The satellite-tracked Hen Harriers that visited Ireland roamed more widely in their first winter and in the early period of their first winter, using multiple roosts, but had more established home ranges from mid-winter and in subsequent winters, as has been recorded for example in Golden Eagles *Aquila chrysaetos* (Miller *et al.* 2017). The availability of multiple roosting opportunities may be an essential

part of a young Hen Harrier's ability to survive their early months of independence, before settling in a preferred area.

The hypothesis that communal roosts are important as centres of information exchange (Ward & Zahavi 1973, Hiraldo *et al.* 1993) may be supported by the observations of birds leaving or arriving at roosts in pairs. Information exchange may be particularly important for birds in their first winter, helping them to find profitable hunting grounds and safe roosting sites. The fact that birds were often observed to arrive at roost sites together suggests that harriers may sometimes meet at pre-roost gathering places. The knowledge that many of the roost sites were used by multiple Hen Harriers (and other species), on a multi-annual basis emphasizes the importance of the roost sites that were found and the need to continue finding as yet undiscovered roost sites. Experience gained by survey volunteers and knowledge of the behaviour of Hen Harriers during the non-breeding season shall be valuable in this regard. The fact that 24% of roosts were in close proximity to breeding sites not only highlights how important those sites are (i.e. hosting Hen Harriers all year) but also suggests that it would be fruitful to further expand non-breeding season surveys in areas where harriers are known to breed. It should not be assumed that Hen Harriers simply leave their breeding grounds after the breeding season has concluded.

Pressures acting on the landscapes and habitats utilized by Hen Harriers in the non-breeding season are widespread and varied. The most common pressure recorded at the roosts themselves was burning of vegetation. This reflects the facts that heath/bog was the most frequently used habitat for roosting and that this habitat is prone to being burned, particularly when classed as ineligible for farm payments (DAFM 2015). The next most common pressure identified was that of renewable energy development, mirroring what was recorded at Hen Harrier breeding sites (Ruddock *et al.* 2016, Wilson *et al.* 2017). Ireland has ambitious targets for renewable energy development and the landscape character types where most wind energy proposals are based (DPHLG 2019) overlap with areas where Hen Harriers reside throughout the year, primarily due to the fact that they are in sparsely populated areas, in open, windy areas and that the lands are otherwise of low economic value. Succession was identified as a pressure where the open habitats that Hen Harriers require were being closed in, for example by scrub regeneration or the growth of plantation forest. At certain sites, Hen Harriers stopped roosting after local

colonization by Common Buzzards, which have expanded their range in Ireland (Balmer *et al.* 2013). This may or may not be coincidental and deserves further attention. While considered by Ruddock *et al.* (2016) as a potentially disturbing influence at breeding sites, none of the 24% of winter roosts where turf cutting was recorded have been lost directly due to peat extraction. One site was deemed to have been abandoned due to degradation of the wider landscape caused by peat milling of raised bogs. Peat extraction for household use occurs during the summer months and, largely, does not overlap with the roosting period. It is worth noting that many of these sites would most likely have been lost if not for peat extraction. During the initial drive for state afforestation of peatlands, many of these sites were only spared from being planted by the fact that they were viewed as a valuable source of fuel. It should be stated however, that vast areas of raised bog habitat have been lost in Ireland through industrial peat milling (NPWS 2007). The loss of natural and semi-natural habitats at roosts resulting from afforestation has already led to the loss of Hen Harrier sites. Afforestation was identified as a threat or pressure at 31% of known roosts as many of the habitats required by Hen Harriers are earmarked for afforestation in the 'Land Types for Afforestation' document published by the Forest Service (2017).

Some of the changes in the landscape surrounding roosts were likely to have undermined the viability of the roost, perhaps on a permanent basis. Pressures acting on Hen Harriers during the non-breeding season may have repercussions on over-winter survival and fitness, which could further exacerbate an already concerning situation in Ireland in relation to population limitation and decline. If the pressures recorded in and around roost sites are happening at a wider national level, which is quite likely, then there may be limited opportunities for displaced birds to move to alternative suitable areas, and the overall carrying capacity of Ireland for Hen Harriers in the non-breeding season may be reduced. While the precise effects at a population level merit further investigation, it is clearly a matter of concern that in the relatively short space of time since 2004, almost a third (31%) of roost sites where the status was known were lost, either by direct disturbance or damage of the roost site, or through wider landscape degradation. Adopting the precautionary principle, both the roost site and the surrounding landscape need to be considered in any conservation efforts to protect the Hen Harrier (and other species sharing these habitats) and steps taken to minimize individual and collective

pressures. Birds of prey are effective indicators of the health of the environment (Sergio *et al.* 2005). If measures were put in place to reverse negative trends, the Hen Harrier could be considered as a 'focal species' (Fleischmann *et al.* 2000), in the expectation that other species (and habitats) derive benefits from conservation action aimed at Hen Harriers. The data collected by the IHHWS can be an instrumental part of designing and targeting such action. Across Europe, the most commonly adopted conservation strategy for Hen Harriers was reported as the designation of protected areas, though this is not always successful (Fernández-Bellón *et al.* 2020), and if roost sites alone were designated, it could carry the risk of highlighting the location of a sensitive species that is subject to disturbance and persecution (O'Donoghue *et al.* 2020). Conservation efforts for wintering Hen Harriers in Ireland could most effectively be delivered through proactive agri-environmental schemes as described in O'Rourke & Finn (2020). The successful measures described by Schlaich *et al.* (2015) for the Montagu's Harrier in the Netherlands, whereby the provision of quality hunting resources is seen as being of fundamental importance (along with protecting the roost sites themselves), could also work for Hen Harriers in Ireland. Financially rewarding landowners for providing enhanced biodiversity would also place a value on maintaining landscapes and livelihoods in what are otherwise economically poorly-performing areas.

Temporal trends of occupation at roosts since the beginning of the study shall be explored in future work. Wing-tagging and satellite tracking data show that Hen Harriers can move between Ireland and Britain (Etheridge & Summers 2006, O'Donoghue 2010, Natural England unpubl. data, RSPB unpubl. data, Hawk and Owl Trust unpubl. data). It is likely that there is net migration to Ireland for the period outside the breeding season, given the milder winter climate in Ireland and the larger population and breeding output of Hen Harriers in Britain, but this is an area that merits further investigation.

The Irish Hen Harrier Winter Survey has been privately co-ordinated and undertaken by volunteers since the winter of 2004/05 and shows what can be achieved through citizen science when comprehensive structures, guidance and supports are put in place. Over 200 roosts have been documented to date, and the intention is that this survey will not only continue to monitor these sites, but will deploy survey effort to find more. Such monitoring on an annual basis may be able to elucidate trends in populations and identify specific risks on a more immediate basis than breeding surveys undertaken on a five-yearly basis. It

will also be important for the various data collected to be examined in detail, to provide new insights on this important aspect of the Hen Harrier's ecology in Ireland. While data gathered by the IHHWS has already been used in safeguarding individual roosts, it is important that a strategic, national and all-island approach is now taken to the conservation of the species outside of the breeding season. Towards this, the data collated by the IHHWS can be used to target, design and implement strategies to safeguard roosts and hunting areas through the avoidance of negative pressures and the support and promotion of positive conservation measures.

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