The breeding biology of Hen Harriers *Circus cyaneus* in Ireland over a five year period

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The breeding biology of Hen Harriers *Circus cyaneus* was investigated between 2007 and 2011 in three study areas in Ireland. The aim of this study was to provide an understanding of the breeding ecology of Hen Harriers in order to inform conservation and land use planning. The number of pairs of breeding Hen Harriers in each of three study areas declined between 2007 and 2011. Nest success and fledged brood sizes were similar across study sites and did not show consistent trends during this period, except in West Clare where success rate of nests decreased. Breeding productivity over the course of the study was low, but was sufficient to allow Hen Harrier populations in these areas to remain stable, provided that juvenile survival and recruitment to the breeding population was sufficiently high. The number of young fledged at successful Hen Harrier nests in this study was, however, quite low relative to other populations. An understanding of basic biology is essential to the development of effective conservation strategies, including those centred on habitat management.

Introduction

The Hen Harrier *Circus cyaneus* is a medium sized, ground-nesting bird of prey that breeds throughout Europe, North America and some parts of Asia, and extends its range further south in the winter to parts of North Africa, Asia and South America. It is widely distributed in Ireland, though relatively rare with an estimated breeding population of around 150 pairs (Norriss *et al.* 2002, Barton *et al.* 2006). The breeding population has recently been estimated at 128-172 pairs in the Republic of Ireland (Ruddock *et al.* 2011) and 63 territorial pairs in Northern Ireland (Sim *et al.* 2007). It is concentrated in the south and west of Ireland, particularly in the counties of Cork, Limerick and Kerry, which support approximately a third of the Irish breeding population. Nests are established during the spring, with each pair producing between one and six eggs. The earliest broods of Hen Harriers may leave the nest during June, but most chicks fledge during July, and are

Plate 67. Hen Harrier chick and eggs (Barry O'Mahony).

independent by August. After the breeding season, some birds remain in the uplands, but many more disperse to milder lowland areas for the winter (O'Donoghue 2010).

Hen Harriers are listed on Annex 1 of the EU Birds Directive (209/147/EC) and remain on the Amber List of species of conservation concern in Ireland due to historical declines and their continued vulnerability to persecution and habitat destruction (Lynas *et al.* 2007). They are consequently protected under Irish and European law. The EU Birds Directive (209/147/EC) requires designation of Special Protection Areas (SPAs) for Hen Harriers in Ireland. At present there are six Hen Harrier SPAs in Ireland, including parts of Clare, Cork, Galway, Kerry, Laois, Limerick, Monaghan, Offaly and Tipperary. The purpose of these SPAs is to protect habitats that are suitable for both foraging and breeding Hen Harriers, which include moorland, bog, rough pasture and young forestry plantations (O'Flynn 1983, Norriss *et al.* 2002, Wilson *et al.* 2006).

Information on both breeding biology and breeding performance, together with an understanding of the factors that limit distribution, are essential in identifying effective planning and conservation measures for bird species (Sutherland *et al.* 2004). This is particularly relevant in the light of the expected sensitivity of the Hen Harrier to forestry and wind energy developments (Bright *et al.* 2008, Pearce-Higgins *et al.* 2009). To this end a long-term study of the breeding ecology of Hen Harriers, funded by the Department of Agriculture, Fisheries and Food, and the National Parks and Wildlife Service (NPWS) has been underway at University College, Cork since 2007. Preliminary findings of this work were reported in 2008 (Irwin *et al.* 2008) and this paper presents an update on those findings at the end of five years of breeding biology research.

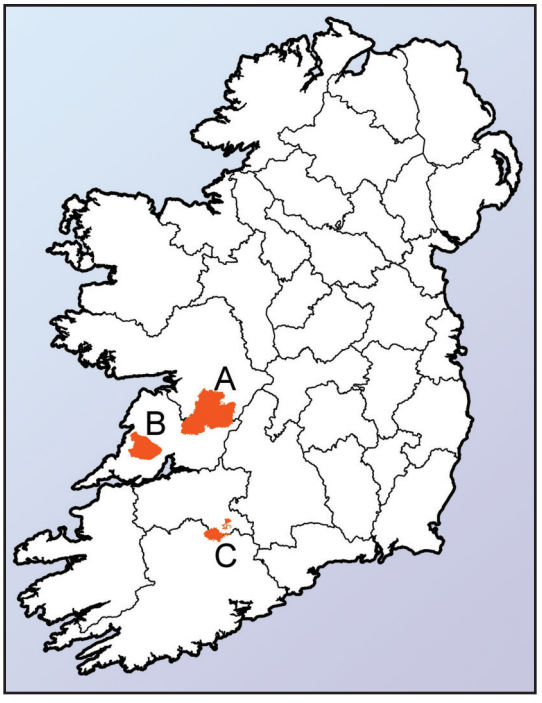

Figure 1. Hen Harrier study areas at (A) Slieve Aughty Mountains, (B) West Clare and (C) Ballyhoura Mountains.

Methods

Data on breeding Hen Harriers were collected at three study sites (Slieve Aughty Mountains, West Clare and Ballyhoura Mountains) in the south of Ireland between 2007 and 2011 (Figure 1). The study site in the Slieve Aughty Mountains is a designated Hen Harrier SPA, while the other two study sites hold relatively dense concentrations of breeding Hen Harriers. The early years of this study also included a site in a designated SPA in Kerry, but as no recent data are available for this site it is not included in the current report.

Data were collected during the breeding season between April and August each year. Territories were located by vantage point watches early in the breeding season at each study area. Breeding territories and subsequent nest locations were identified, typically between April and June, by utilising vantage point watches to observe the behaviour of territorial pairs before and during nest-building and laying, and by tracking females back to the nest after they had accepted food-passes from males during incubation and brooding.

Nest visits were then undertaken (under licence from NPWS) to gather information on breeding biology. This included information on timing of breeding (first egg, hatch and fledge dates), clutch size, brood size and nest failure (timing, cause) or success. Initial visits were made to nests to identify breeding attempt status and nest contents, with a final visit to ring and wing-tag chicks when they were approximately four weeks old. Nest visits were not conducted where this was deemed to pose too great a risk to the success of the breeding attempt, either by drawing the attention of potential predators to the nest, or by facilitating access to the nest by predators though trampling of surrounding vegetation. Fieldwork continued until early August, with all nests being monitored until they had either failed or fledged. Nest cameras were also installed at a subset of nests to supplement data acquired by visual observation in study sites. Detailed information on study sites and methodology can be found in Irwin *et al.* (2008).

At almost all of the visited nests the young were wing-tagged, so their nest of origin could be identified with certainty post-fledging. Nests where chicks were not wing-tagged were recorded as successful if juveniles were observed

flying in the nest area. Because the age when chicks were wing-tagged (typically 25-30 days) was close to the age when they normally fledge (usually <39 days), the number of chicks recorded as having fledged from successful nests was estimated as the number of chicks present on the final visit. This was amended when young birds were observed to have perished subsequent to the final visit but prior to fledging. For nests that were not visited, the number of fledglings was estimated as the maximum number of juveniles seen flying in the nesting area post-fledging. For the purpose of calculating the number of 'exposure days' (i.e. the number of days during which the fate of nests was monitored) for each nest, observations were taken from the date that nests were located with sufficient certainty to track the success of the breeding attempt. The date on which a brood fledged or failed, where this was not known, was taken as the midpoint in time between the date the nest was last seen active, and the date on which fledging or nest failure was proven. Means are presented ± standard error of the mean.

Only nests with known breeding outcomes were used in the following calculations. Three main measures of the breeding success of the population were calculated. Fledged brood size was calculated as the average number of young fledged from successful nests. Breeding productivity was calculated as the average number fledged across all nests. Finally, nest success rate was calculated as the percentage of nests that fledged at least one young. This method commonly overestimates success due to the failure of some nests before location by researchers, creating a bias towards successful nests. In order to address this the Mayfield method was used to calculate daily survival rates, and to estimate success rates of nests in this study (Mayfield 1975). The effects of year and study area on success rate (the probability of nests fledging one or more young) were investigated using logistic exposure models (Schaffer 2004), which take account of the effect of the age at which nests were found on observed probabilities of success. Logistic exposure models were specified using the GLM function in R (R Development Core Team 2008), with a user-defined link function (Schaffer 2004). Models were selected using backward selection from a fully specified model, selecting the model with the lowest AIC (Akaike Information Criterion), until further removal of any terms remaining in the model increased the AIC. Only the results of the final model are presented.

At nests that were deemed suitable for visiting, chicks were ringed (with BTO rings) and wing-tagged under licence, where possible at around 25 days after hatching, during the final nest visit. Chicks were sexed using eye colour and tarsus measurements. The wing-tagging scheme initiated in 2006 by the Irish Raptor Study Group (IRSG) was enhanced significantly during this project. Wing tags were made from PVC nylon and were attached to the birds by fastening the tag through the patagium (between wrist and shoulder). Several morphometric measurements (weight, wing length, tarsus length and width) were recorded from each nestling. The colour of the right wing-tag was specific to the study area (Ballyhoura = Yellow, West Clare = Green, Slieve Aughty = Black), while the colour of the left wing-tag represented the year of tagging (2007 = Red, 2008 = Green, 2009 = Yellow, 2010 = Black, 2011 = Orange). In addition, an individual alphanumeric identifier was included on each tag to facilitate identification of individual birds. In observations of tagged birds at natal areas, tag letter/number markings could be read at a distance of 250m (using binoculars) when birds were perched. A poster scheme was undertaken to advertise the colour scheme and solicit feedback of sightings from the general public, and details were also submitted to the European colour-ring Birding website (www.cr-birding.be).

Results

Nest success

Here we report on the outcome of 142 nests in the three study areas between 2007 and 2011. Forty-seven nests were found in the Slieve Aughty range, 47 in the Ballyhoura range and 48 in West Clare. The number of nests in each study area decreased over the course of the study (Figure 2). Of these 142 nests, 74 (52%) successfully fledged at least one Hen Harrier chick. The success rate of nests decreased over the course of the study in West Clare, but showed no clear pattern in the other two areas. The highest success rate in any combination of study areas and years (80%) was observed in West Clare in 2007 and the lowest (22%) in West Clare and Slieve Aughty in 2010 and 2007, respectively (Figure 3). The success rate of all nests over the five years of this study was higher at Ballyhoura (60%) than at West Clare (54%) or Slieve Aughty (43%). The Mayfield estimate of daily success probability ranged from 0.966 to 0.997 in each of the areas,

Figure 2. Number of Hen Harrier nests located at each study area in each year.

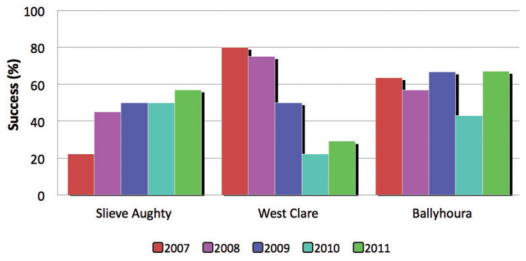

Figure 3. Percentage of Hen Harrier nests producing fledged young at each study area in each year.

and the estimate of success rate of nests used in this analysis ranged from 7% to 76% (Table 1). The effects of study year study area, and the interaction between year and area on the success of nests were significant (Table 2). The Slieve Aughty range had a significantly lower success than the other two areas, which were not significantly different from each other. This pattern appears to have been driven by a particularly low rate of success in the Slieve Aughty range in 2007. In the latter years of the study (2009, 2010 and 2011) nests in Ballyhoura and West Clare had significantly lower success than they did in 2007.

In addition to the 142 nests included in this analysis, territorial behaviour (e.g. displays, food-passes, nest building) was also observed in a number of areas where no evidence of nesting was subsequently found. In such cases, adults either abandoned the territory before initiating a nesting attempt or the nesting attempt failed before a nest could be found. The number of these abandoned/early and failed territories is provided in Table 3.

Table 1. Measure of breeding success of Hen Harriers in each study area between 2007 and 2011 (n = number of nests used in calculation; DSP = Daily Survival Probability; MES (%) = Mayfield Estimate of Survival; N = Number of exposure days used in calculation of MES).

Study Area	Year	n	DSP	MES (%)	N
Slieve Aughty	2007	6	0.974	13	155
	2008	8	0.995	57	424
	2009	12	0.986	34	437
	2010	6	0.981	23	212
	2011	5	0.984	29	193
West Clare	2007	10	0.997	76	580
	2008	10	0.996	74	525
	2009	10	0.978	18	232
	2010	7	0.966	7	205
	2011	7	0.980	21	250
Ballyhoura	2007	10	0.993	59	439
	2008	8	0.995	69	419
	2009	9	0.993	57	423
	2010	7	0.984	28	245
	2011	5	0.996	71	225

Table 2. Output of Binomial Generalised Linear Model of breeding success of Hen Harriers with study year, study area, and the interaction between year and study area included as explanatory variables. AIC = 262.09. In line with common practice in GLMs, the first level of each factor included in this model ('2007' for year, 'West Clare' for study area, and '2007:West Clare' for the interaction between these variables) is incorporated within the model intercept in order to reduce the number of parameters in the model.

	Estimate	Se	Z value	Pr(>|z|)	P
(Intercept)	5.6634	0.7237	7.825	5.06E-15	<0.001
2008	-0.5322	0.9314	-0.571	0.56777	ns
2009	-2.0342	0.8816	-2.307	0.02104	<0.05
2010	-2.6012	0.8588	-3.029	0.00246	<0.01
2011	-2.1952	0.8874	-2.474	0.01337	<0.05
Ballyhoura	-0.9665	0.9021	-1.071	0.28401	ns
Slieve Aughty	-3.3016	0.8727	-3.783	0.00016	<0.001
2008:Ballyhoura	0.0608	1.1615	0.052	0.95827	ns
2009: Ballyhoura	2.1277	1.1971	1.777	0.07551	ns
2010: Ballyhoura	1.8343	1.1779	1.557	0.11940	ns
2011: Ballyhoura	2.1991	1.2822	1.715	0.08633	ns
2008: Slieve Aughty	2.4276	1.1460	2.118	0.03415	<0.05
2009: Slieve Aughty	3.8223	1.1111	3.44	0.00058	<0.001
2010: Slieve Aughty	3.5796	1.1351	3.154	0.00161	<0.01
2011: Slieve Aughty	3.6327	1.1938	3.043	0.00234	<0.01

Table 3. The number of Hen Harrier pairs in each study area that abandoned their breeding attempts before nests were found, and so were not included in the present study, 2009 to 2011. The minimum number is the number of territories that showed strong evidence of pair bonding, and the maximum number is the total number of territories where territorial behaviour was observed.

Area	Ballyhoura		Slieve Aughty		West Clare	
Year	Min	Max	Min	Max	Min	Max
2009	1	4	8	11	2	6
2010	5	5	9	14	2	6
2011	2	5	2	7	2	3

Productivity

Clutch sizes ranged from two to six with the most common (48% of nests) being four eggs. The maximum number of chicks fledged from successful nests was 4.0, and the average was 2.4 (±0.1). Overall, the number of chicks produced by successful nests was slightly higher in West Clare (2.8 ± 0.2) than in Ballyhoura (2.1 ± 0.2) or Slieve Aughty (2.3 ± 0.2) (Figure 4). The average number of chicks fledged from all successful and unsuccessful nests (breeding productivity) during this study was 1.4 (0.3). Breeding productivity over the course of the five years of the study was 1.9 in West Clare, 1.3 in Ballyhoura and 1.0 in Slieve Aughty, and showed a decline in West Clare only.

The total number of fledged young produced by Hen Harrier pairs in the three study areas over the five years decreased slightly over the course of this study. Thirty-eight fledged in 2007, 61 in 2008, 35 in 2009, 21 in 2010 and 25 in 2011.

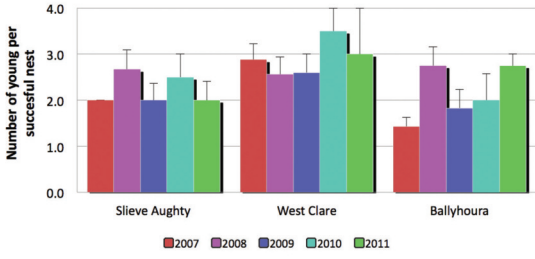

Figure 4. Mean (±se) number of chicks of Hen Harrier produced in each study area in nests included in this study.

Wing-tagging

One hundred and seventy nestling Hen Harriers were marked using colour-coded wing-tags during this study in the three study areas. Forty were tagged in 2007, 69 in 2008, 25 in 2009, 20 in 2010 and 16 in 2011. Forty eight percent of wing-tagged nestlings were male and 52% were female. Very few wing-tagged birds have been recorded during subsequent breeding seasons. One bird wing-tagged in Slieve Aughty in 2008 is known to have subsequently returned and bred there in 2010 and 2011, and to have over-wintered in Galway in 2008 and 2009. Two nestlings wing-tagged in Ballyhoura were subsequently recorded (separately) in Slieve Aughty and Ballyhoura, though neither was recorded to have bred. Wing-tagged birds have been recorded more frequently at communal winter roosts than they have during the breeding season (O'Donoghue 2010).

Food pass, Rebecca Whatmore.

Discussion

The annual number of nestling Hen Harriers produced by the three main study areas ranged from 21 to 61 during the period 2007-2011 and showed a slightly decreasing trend over time. The number of nests ranged from 19 to 38 over the same period. The breeding productivity of these nests (1.4 ± 0.3) is in keeping with that reported for Hen Harriers in other parts of their range (Natural England 2008), with declining populations generally being less productive (Amar *et al.* 2007). However, the average of 2.4 (± 0.2) chicks fledged per successful breeding attempt is lower than reported in the UK, where the average brood size at fledging from successful nests was found to be more than three chicks (Fielding *et al.* 2011). Moreover, if some of the territorial pairs where no nests were found initiated nesting attempts but failed early on, the true success rate of the Hen Harrier populations we studied may be considerably lower. As it stands, our estimate of breeding productivity is not very high, but is above the threshold for stable or increasing populations identified by a recent study of Hen Harriers in the UK (Fielding *et al.* 2011). However, productivity alone is not the only factor determining population stability, which also depends on survival of juvenile and adult birds. The evidence to date suggests that juvenile survival may be quite low, as there has been a very poor return rate of wing-tagged birds to breeding areas (O'Halloran, unpublished data).

The decline in the number of juvenile Hen Harriers produced in each study area over the course of the study was largely a consequence of the decreasing number of nests over the five years of the study, with nest success and fledged brood size of successful nests remaining relatively stable. The decline in the number of nests in our study areas may be related to land-use change or habitat availability, as reported in Scotland (Meek *et al.* 1998, Amar and Redpath 2005). Prior to large-scale afforestation in the uplands, the majority of Hen Harriers in Ireland, and elsewhere, bred in open habitats such as moorland, bog and rough pasture (Redpath *et al.* 1998, Sim *et al.* 2001, Norriss *et al*. 2002, Wilson *et al.* 2006). These habitats have become less abundant in the uplands as a result of agricultural intensification and afforestation. Hen Harrier populations in Ireland have exhibited historic fluctuations, some of which can be related to the expansion of forestry (Cramp and Simmons 1980, O'Flynn 1983). The negative effects of habitat loss and degradation on Hen Harrier populations are thought to be mediated principally through the effects of habitat on food availability (Amar *et al.* 2003, Thirgood *et al.* 2003).

Though much of the Hen Harriers' traditional breeding area in Ireland is now forested, they appear to have adapted to the decline in suitable open habitats by utilising forests both for foraging and for nesting. Recent research has

Plate 68. Hen Harrier (Jamie Durrant).

demonstrated that upland forested landscapes can be positively selected as a nesting habitat by Hen Harriers (Wilson *et al.* 2009). In this context open, pre-thicket plantation forest is utilised more often than any other available habitat in our study areas for nesting by Hen Harriers. Increasingly, selection for second rotation pre-thicket is becoming stronger than for first rotation pre-thicket (Wilson *et al.* 2009). This trend could be due to underlying differences in this stage of commercial forest between the first and second rotation (Sweeney *et al.* 2010), but ongoing changes in the nature and location of afforestation sites may also be a contributing factor. Most forests that are currently in second rotation were planted a minimum of three to four decades ago, when afforestation was concentrated in upland, peatland sites (Wilson *et al.* In press). More recently, afforestation has shifted towards grassland habitats in lowland sites with mineral soils. Many such habiats are not available to Hen Harriers nesting in upland areas, and in those that are, the nesting cover provided by the developing vegetation may be less attractive than that found in pre-thicket forests on peat. Investigation of the success rates of Hen Harrier nests in different habitats revealed no effect of either total forest cover or closed canopy forest cover on either nest success rates or fledged brood size. However, pre-thicket second rotation forest cover was negatively related to nest success, both at the nest site and at a 2km scale, though only in Slieve Aughty (Wilson *et al.* 2010).

Our data suggests that, at least in some parts of their range, Hen Harrier numbers in Ireland are decreasing and that low levels of breeding success may be a contributing factor in this decline. Some of the patterns evident in our data may help to deduce the likely causes of these declines. Firstly, in two of our study areas, nest success was consistently moderate to poor over the five years of the study, but nest success in West Clare declined steadily over the total period. There are

several possible reasons for this, none of which are mutually exclusive. Firstly, it is possible that mortality of breeding adults increased during this period. In 2010 and 2011, the carcasses of three adult females were found by their nests in this area. The cause of these mortalities is unknown, nor do we know whether other nest failures were precipitated by the death of a parent bird during the breeding attempt.

A second possible explanation for the decrease in the success of nests in West Clare is that there may have been a local change in the abundance or activity of nest predators. Large-scale afforestation has taken place more recently in West Clare than in our other two study areas, and it is possible that this has led to an increase in abundance of nest predators such as Pine Martens *Martes martes* and Red Fox *Vulpes vulpes.*

Finally, changes in prey availability during our study may have played a part in the decreased nest success of Hen Harriers in West Clare. The winters of 2009/10 and 2010/11 were unusually severe, resulting in declines in the populations of some resident passerines, particularly in the upland areas where Hen Harriers breed. West Clare is at a lower altitude and is closer to the coast than our other study areas, so would normally experience milder winters. It is therefore possible that the bird community of this area was not as well adapted to harsh winter conditions, and so was more badly affected by the extreme nature of the past two winters.

A second pattern that can be seen from our data is that, although the number of breeding pairs in each of our study areas has declined over the study period, numbers breeding in 2008 were higher in all areas than in any other year. One possibility is that conditions for breeding in that year were better than in the others. Neither nest success nor fledged brood sizes were noticeably higher in 2008 than in other years, suggesting that breeding conditions may not have been unusually good. However, the relationship between per-pair measures of breeding success and annual conditions may be confounded by density-dependent effects. Another possibility is that the high numbers of breeders in the summer of 2008 may have been due to elevated numbers of Hen Harriers available for breeding. Most Hen Harriers do not breed in their first year, so increased numbers of birds available to breed could have been caused by elevated levels of breeding productivity in 2006 (or earlier) or by unusually high levels of survival through the winter preceding 2008. Our data do not extend before 2007, and we do not have data on winter movements or survival, and so this hypothesis can not be tested at present.

Conservation of bird species is typically delivered through habitat management and protection, and in this regard there is potential for conflicts between Hen Harrier protection and land use. Most famously, management of upland areas for grouse shooting in the UK has led to persecution of Hen Harriers on levels that continue to threaten the species persistence in some parts of Britain. Conflicts in Ireland are not currently as overt as this, but social and economic pressures to develop the upland areas are considerable. The future of Hen Harriers in areas subject to afforestation and wind energy developments depends on their ability to adapt to the resulting changes in their habitat and in the ability of society to put in place effective mitigation and habitat protection in situations where adaptation is insufficient.

Recent studies confirm that Hen Harriers can breed successfully in Irish forested landscapes (Wilson *et al.* 2009, 2010). However, we need to improve our understanding of the ways in which forest management can affect Hen Harrier breeding success, through factors such as predation pressure and prey availability. A number of SPAs (Special Protection Areas) have now been designated for the protection of breeding Hen Harriers in Ireland. Conservation management within these areas aim to ensure that they remain suitable for Hen Harriers and that activities carried out within them, especially during the breeding season, do not change the favourable conservation status of Hen Harriers. In addition, areas known to be important to wintering birds, either for foraging or for communal roosting should be given appropriate protection. This could be achieved either by giving the most important areas a formally designated status similar to that of breeding SPAs, or by country-wide measures that afford all areas used be Hen Harriers an adequate level of protection.

In light of the increasing demand for energy from renewable sources, and an associated increase in wind farm proposals in Ireland and elsewhere, there is increasing interest in evaluating the potential conflict between wind farms and Hen Harrier conservation (Bright *et al.* 2008, Pearce-Higgins *et al.* 2009). In this respect, basic information on the breeding biology of this species, such as provided here, is essential to the evaluation of the effects of wind farm developments, particularly cumulative impact assessment. This information is also necessary for the development of conservation measures and management strategies for this species in Ireland, as required under EU directives. However, proper assessment of the risk posed by wind energy developments to Hen Harriers requires more detailed information about the implications of such developments for adult survival and the degree to which wind farms result in habitat displacement for Hen Harriers.

We need to improve our understanding of the factors affecting juvenile survival and subsequent recruitment to the breeding population. In this regard, information on sightings of wing-tagged birds are extremely valuable, as they inform our understanding of the post-natal movements of young birds, the habitats they use and the factors that may contribute to their survival, and (equally importantly) the life-expectancy of wing-tags deployed on Irish harriers. Data generated by satellite tags deployed on young Hen Harriers before they

leave the nest would also be invaluable. These could reveal detailed information about the movements of individual juveniles, allowing us a much greater insight into the factors determining survival and, ultimately, recruitment of young Hen Harriers into the breeding population.

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