



Environment No. 10

© COFORD 2010

- *Hen Harriers breed in open, upland habitats such as heather moor, bog, scrub, grasslands and young conifer plantations. Habitat loss and persecution up to the mid-twentieth century resulted in a significant reduction in the population in Ireland. Recovery in recent decades is related to an increase in the prevalence of young conifer plantations during this period of extensive state afforestation.*
- *Forests are an important feature in the Hen Harrier's landscape. Striking the right balance between forest types and stages, together with minimising other negative impacts, will play a large part in determining the future distribution and presence of this threatened Irish bird of prey.*
- *The EU Birds Directive (79/409/EEC) requires designation of Special Protection Areas (SPAs) for Hen Harriers in Ireland. If Ireland fails to do so, sanctions may be imposed by the European Court.*
- *Six sites that provide suitable habitat are currently designated as Special Protection Areas (SPAs) for Hen Harriers incorporating land in counties Clare, Cork, Galway, Kerry, Laois, Limerick, Monaghan, Offaly, and Tipperary.*
- *These SPAs include peatland habitats such as heath and bog, rough grassland, as well as conifer plantations, all of which are important for Hen Harriers.*

COFORD

Dept. Agriculture, Fisheries & Food
Agriculture House, Kildare Street
Dublin 2, Ireland
Telephone: +353 1 607 2487
Email: info@coford.ie
<http://www.coford.ie>



The use of forested landscapes by Hen Harriers in Ireland

Mark Wilson, Sandra Irwin, Barry O'Donoghue, Tom Kelly and John O'Halloran

Background

Recent global estimates suggest that there are approximately 11 million species of plants and animals living today, with new finds continually being made (Chapman 2009). Forests are home to a major portion of this biodiversity. Despite the rich and varied nature of life on earth, biodiversity is being reduced on a massive scale, primarily through the actions of mankind in depleting suitable habitats (Sinha 1998). Protection of biodiversity has now become a global priority and in Ireland biodiversity conservation is governed by national and European legislation. The Hen Harrier is a good example of a species that can be protected and its status enhanced through appropriate habitat management.



Plate 1. Female Hen Harrier.

Photograph: Richard T. Mills.

Over recent centuries a number of raptor species have been lost from the island of Ireland, and the Hen Harrier, one of our rarest birds of prey, is now classed as vulnerable here and at a European scale. Its decline has been associated with habitat loss and persecution (Watson 1977; O’Flynn 1983). Traditionally this species used heather moors for nesting during the breeding season and foraged in the surrounding landscape which included extensive farmland. Due to the depletion of significant proportions of suitable habitat from the Irish landscape by afforestation or reclamation, they have adapted to nesting in young conifer plantations and are now frequently associated with these forests. Ireland is required under European law to designate areas of land that will be managed for the conservation of this species, and in order to adequately provide for the conservation of this bird we need a detailed understanding of their biology and how they interact with habitats both locally and at a landscape scale. Knowledge of breeding biology is crucial in formulating effective conservation management plans. To meet this demand a research project, jointly funded by COFORD and the National Parks and Wildlife Service (NPWS), is being undertaken at University College Cork (UCC) to provide the objective scientific data needed to fill gaps in our knowledge and ensure the protection of Hen Harriers in Ireland. Previous studies have gathered some information by direct observation and systematic surveys, which are both time-consuming and difficult. The team at UCC are using these traditional methods in combination with recent advances in appropriate technologies to gather the required ecological and demographic information. This note presents some of the preliminary findings of this detailed six year study, which will run until 2012.

Hen Harriers in Ireland

Historically widespread in Ireland, population fluctuations in recent centuries throughout Europe have led to an overall population decline of Hen Harriers (Ferguson-Lees and Christie 2001). Despite an apparent recent recovery in the Irish population, the most recent national survey estimated that only 150 breeding Hen Harrier pairs remain in Ireland today (Barton et al. 2006). They remain on the Amber List of species of conservation concern in Ireland due to their continued vulnerability to persecution and habitat destruction (Lynas et al. 2007).

Watson (1977) reported that, during the early 19th century, Hen Harriers bred in all areas of Ireland where suitable habitat was available. The first evidence of a decline in population comes from the middle of that century, with numbers continuing to fall until the middle of the 20th century, when there were believed to have been very few breeding pairs left in Ireland (O’Flynn 1983). However, from the 1950s, the Hen Harrier population in Ireland underwent a dramatic recovery. Anecdotal records suggesting that by the mid 1970s as many as 250-300 may have been breeding in Ireland (O’Flynn 1983). Land use changes during the late 20th century resulted in a further significant decline in Hen Harrier numbers in Ireland (O’Flynn 1983; Norriss et al. 2002). Although some recovery has been reported recently, more intensive surveys may be partly responsible for this observation, and continued protection is required to ensure future recovery of this species in Ireland (Lynas et al. 2007).

Hen Harriers and the law

Hen Harriers are currently vulnerable across much of their European range, and are consequently protected under Irish and European law, and subject to conservation measures in many countries. Ireland is committed to the conservation of biological diversity under a variety of international agreements, and forestry practice in Ireland should conform to Sustainable Forest Management, a core component of which is biodiversity conservation. The primary instruments of biodiversity conservation are protection of forest ecosystems through establishment of Special Protection Areas (SPAs) and management of forests in a way that takes biodiversity into account.

Hen Harriers are listed, along with 32 other rare and vulnerable bird species, on Annex 1 of the Birds Directive (79/409/EEC). This instrument legally requires Ireland to ensure their protection and to designate a suite of the most important sites for this species as SPAs, or else face heavy fines in the European Court.

The six designated SPAs are:

- SPA (004160): Slieve Bloom Mountains (Laois and Offaly);
- SPA (004161): Stack’s to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle (Cork, Kerry and Limerick);

- SPA (004162): Mullaghanish to Musheramore Mountains (Cork);
- SPA (004165): Slieve Felim to Silvermines (Limerick and Tipperary);
- SPA (004167): Slieve Beagh (Monaghan);
- SPA (004168): Slieve Aughty Mountains (Clare and Galway).

These Hen Harrier SPAs include heaths and bogs, rough grassland and conifer plantations, as these habitats are all important breeding areas for the species. Activities requiring regulation within SPAs relate mainly to conversion of peatlands to other land use types, removal of hedgerows, and the recreational use of off-road vehicles, which are not permitted in circumstances where they will have a significant adverse affect on the SPA. Proposed wind farm developments are currently assessed through the planning process, and potential impacts assessed on a case-by-case basis.

Hen Harriers and forests

The traditional breeding habitat of Hen Harriers in Ireland is open moorland, bog and rough pasture in the uplands (Redpath et al. 1998; Sim et al. 2001; Norriss et al. 2002; Wilson et al. 2006). Habitat loss and degradation has long been considered a significant contributing factor in the decline of Hen Harrier populations, an impact mediated through its effect on food availability (Amar et al. 2003; Thirgood et al. 2003).

The suitability of many upland areas in Ireland for Hen Harriers was reduced by agricultural intensification and afforestation during the late 20th century. As open spaces were replaced by forest plantations, the ground vegetation of these young plantations provided a suitable habitat for Hen Harrier nesting and foraging (O'Flynn 1983; Redpath et al. 1998; Madders 2000). Hen Harriers adapted to these forested landscapes to a remarkable degree, and at least in some parts of its Irish range, it now inhabits heavily forested areas (Wilson et al. 2009). While Hen Harriers nest and forage in young plantations, they do not use this habitat as extensively following canopy closure, and the maturation of upland conifer plantations may limit the availability of suitable breeding and foraging sites (Picozzi 1978; O'Flynn 1983; Sim et al. 2001; O'Donoghue 2004). As closed

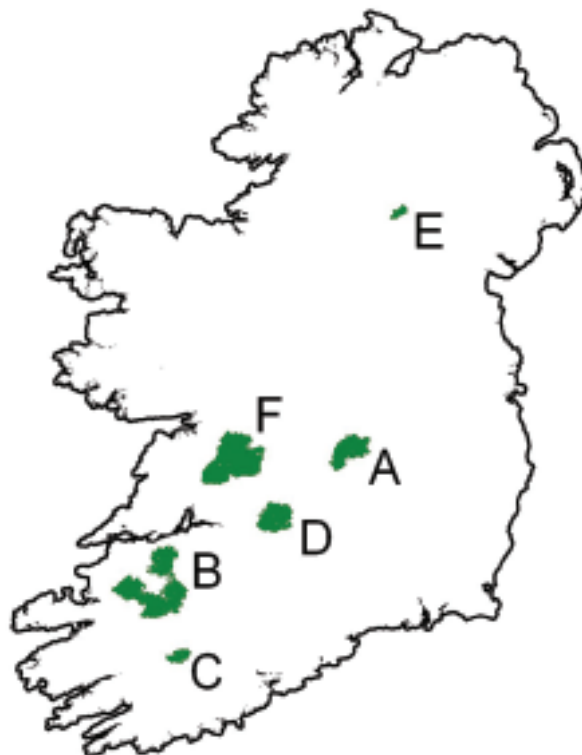


Figure 1. Special Protection Areas for Hen Harriers in Ireland.

canopy forest persists for about two thirds of the plantation forest cycle, afforestation of open habitats that are used by Hen Harriers will ultimately lead to a net loss of suitable habitat, even if they use forests at pre-thicket stage (Bibby and Etheridge 1993). While recent studies suggest that Hen Harriers make use of pre-thicket forest in both first and second rotation plantations in Ireland (Norriss et al. 2002; O'Donoghue 2004), use of second rotation pre-thicket has only rarely been reported in Great Britain (Petty and Anderson 1986; Madders 2000). Also, because of a lack of vegetation following clearfelling, and the more rapid closure of the forest canopy following planting, it is likely that second rotation plantations typically provide suitable habitat for a shorter period than newly planted first rotation forests (O'Donoghue 2004). It is therefore likely that Hen Harriers will require substantial areas of open habitats if they are to persist in extensively afforested landscapes (Wilson et al. 2009).



Plate 2. Typical densely vegetated Hen Harrier nest site in pre-thicket stage second rotation Sitka spruce forest in Ireland.

Photograph: Mark Wilson.

Hen Harrier nesting habitat

A recent study published by UCC on nest site selection by Hen Harriers in six of the areas covered by the 2000 and 2005 National Hen Harrier Surveys revealed that pre-thicket plantation forest was more strongly selected by Hen Harriers in all six study areas during both survey years than any other habitat (Wilson et al. 2009). This study examined both first and second rotation pre-thicket plantations, closed canopy plantations, improved grassland, peatland habitats and rough pasture. Selection for second rotation pre-thicket plantations was even stronger than for first rotation pre-thicket plantations. In fact, during the 2005 survey, nests were more frequently situated in second rotation pre-thicket plantations than in any other habitat, despite the fact that

second rotation forest represented less than 5% of all study areas, demonstrating a clear preference for this habitat for nesting (Figure 2). This represents an interesting difference between the Irish Hen Harrier population and those studied elsewhere so far, and means that the contribution that forest habitat can make to providing suitable landscape for Hen Harriers can be incorporated into future planning.

The rapid recovery of vegetation in clearfelled sites provides plentiful cover for ground-nesting birds typically associated with open habitats (Bibby et al. 1985; Burton 2007). In addition, the combination of brash and growing vegetation in second rotation forests can offer protection from predators (Truscott et al. 2004). Despite these obvious advantages, a preference for young second rotation plantation forests for nesting Hen Harriers has not been

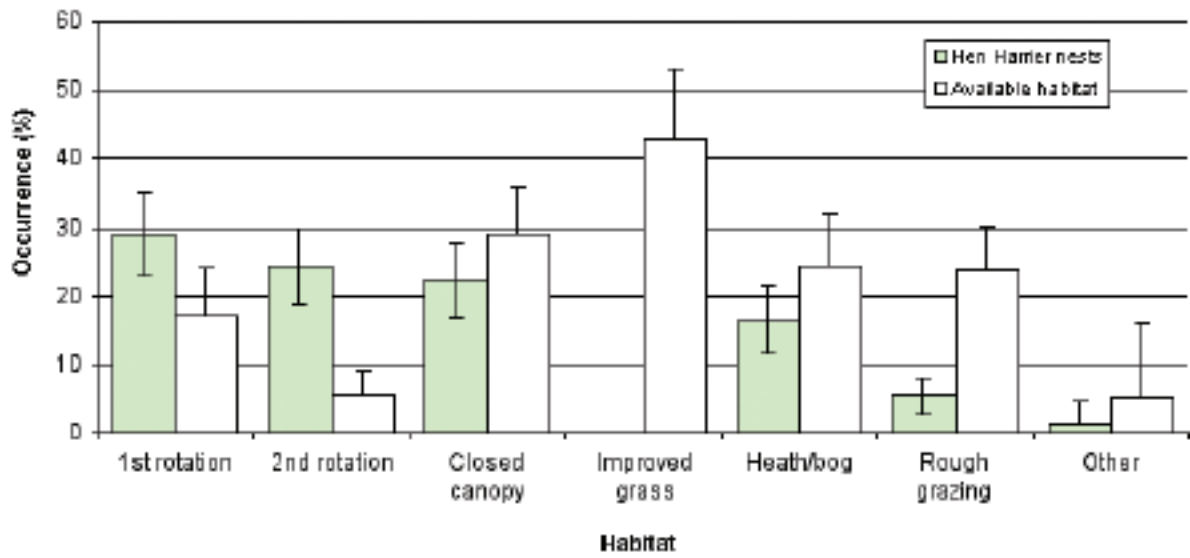


Figure 2. Distribution between habitat types of Hen Harrier nests and random points (representative of available habitat) during the 2000 and 2005 National Irish Hen Harrier Surveys (Error bars show 95% confidence intervals for these proportions) (Wilson et al. 2009). Where the shaded bar exceeds the white bar it indicates that there are more nests located in this habitat type than expected at random.



Plate 3. Newly hatched Hen Harrier in active nest.

Photograph: Barry O'Mahony.

reported in Great Britain, where heather-dominated habitats have been found to be the most important for nesting and foraging Hen Harriers (Redpath et al. 1998; Redpath et al. 2002; Amar and Redpath 2005; Sim et al. 2007). Interestingly, heath/bog was not selected as often as expected for nest sites in the Irish study (Figure 2). Many Irish peatland habitats are overgrazed (MacGowan and Doyle 1996; McKee et al. 1998), which could reduce their usefulness to Hen Harriers by decreasing cover for nesting (Redpath et al. 1998) and lowering prey densities (Madders 2000).

Although improved grassland was the most abundant habitat in the study areas, occupying more than 40%, no nests were found in this habitat. This habitat contains little suitable cover for nests, and areas dominated by improved grassland tend to be at lower altitude and have higher levels of human activity than areas of other upland habitats. Rough grazing was not so comprehensively avoided, but a far smaller proportion of nests were situated in this habitat than might be expected through random selection (Figure 2) and nests located in rough pasture were frequently associated with localised areas of gorse (*Ulex* spp), willow (*Salix* spp) or other low shrubs.

Hen Harrier habitat use

Male Hen Harriers typically range over distances of several kilometres from the nest during the breeding season, but intensity of foraging activity is much greater within 2 km of the nest than beyond this distance (Madders 2003; Arroyo et al. 2006). Therefore, data from the two recent Irish Hen Harrier Surveys were used to investigate habitat composition around the nest site by comparing the habitat within 2 km of known nest sites with habitat within 2 km of randomly selected points within the study sites (Wilson et al. 2009). Habitat within 2 km of nests differed from that expected if nest sites were selected at random with respect to habitat. Cover of pre-thicket plantations, closed-canopy plantations and heath/bog was greater around nests than around the randomly selected points, while cover of improved grassland and rough pasture was lower than random. The areas of post-closure plantation, heath/bog and other within 2 km of nests were significantly greater than random in both surveys, though numbers of nests situated in these habitats were not significantly different from random. However, it was not possible to completely separate the

influence of selection for habitat at the nest site itself from that of selection operating at a wider, landscape scale as these two variables are related to one another, and could both play a part in nest site selection. Hen Harriers could choose to nest in a patch of second-rotation pre-thicket plantation because of the opportunities it affords for shelter and concealment of their nests, because it is advantageous to nest in landscapes that contain relatively high levels of second rotation plantation cover around them, or for a combination of these factors. However, differences between nests and randomly selected points located in Hen Harrier nesting habitats indicate that at least a component of nest site selection was based on landscape scale factors. These findings suggest that most variation in Hen Harrier nest site location can be explained in terms of selection of preferred nesting habitats and avoidance of landscapes with a high proportion of improved grassland (Wilson et al. 2009).

Selection of nests sites situated in landscapes with low levels of improved grassland cover could therefore be due to avoidance of areas with low foraging profitability. Previous studies found that improved grassland is used infrequently by hunting Hen Harriers (Madders 2000; O'Donoghue 2004; Barton et al. 2006) and that the density of prey species in agricultural land is negatively related to intensity of farming (Butet and Leroux 2001; Vanhinsbergh and Chamberlain 2001). Alternatively, the lack of cover that makes improved grassland unsuitable as a nesting habitat could also render nearby patches of potentially suitable nesting habitat less attractive, by making it harder for adult Hen Harriers to approach the nest without being observed by potential nest predators and humans. There was no evidence for avoidance of areas with high post-closure plantation cover. This indicates that, at least at current levels and configurations of plantation cover, the presence of post-closure plantation forest in otherwise suitable habitat does not greatly limit the distribution of breeding Hen Harriers within the main parts of their Irish range.

The proportional change in the number of breeding Hen Harrier pairs in the six study areas between 2000 and 2005 in study areas was positively correlated with the change in the proportion of second rotation pre-thicket plantations within 2 km (Figure 3). The proportional change between years in area within 2 km was not correlated with changes in the number of breeding Hen Harriers for any of the other habitats. As the proportion of first rotation forests in our landscape declines there is an associated increase in second

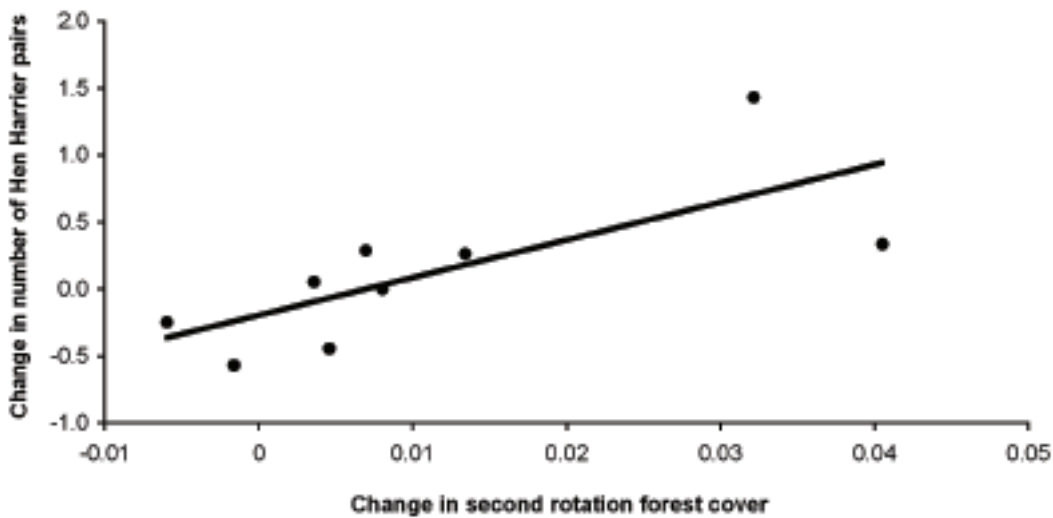


Figure 3. The proportional difference in the number of breeding Hen Harriers in study areas between 2000 and 2005, plotted against the proportional change in percentage cover of pre-thicket second rotation plantations during this period.

rotation or restock plantations which will continue to increase in the future and in heavily afforested areas will constitute a large proportion of the habitat available to Hen Harriers for nesting and foraging.

With regard to the management of land within Special Protection Areas, an understanding of the usefulness of forest habitats for breeding Hen Harrier is vitally important and has been the subject of a number of investigations in different parts of the world, the findings of which have so far been inconclusive. Hen Harriers in Great Britain are reported to use young second rotation forests as hunting grounds during the breeding season (Madders 2000; Sim et al. 2007) although they have only occasionally been reported to use this habitat for nesting (Petty and Anderson 1986). In the US, reforestation is considered a factor contributing to the decline in Hen Harrier populations (Serrentine 1992; MacWhirter and Bildstein 1996). There is, however, no evidence of active avoidance of second rotation forests by Hen Harriers in continental Europe or North America.

While Hen Harriers in this study by Wilson et al. (2009) clearly avoided intensively managed agricultural land, there was no evidence that they avoided breeding in areas with a proportion of forested land. In fact, pre-thicket second rotation forest was strongly preferred as a nesting habitat, providing encouraging evidence of the possible co-existence of Hen Harriers and forests in Ireland.

Hen Harrier breeding success

The incidence of Hen Harriers nesting in Ireland's newly forested landscapes described above does not guarantee their persistence in these areas. As part of ongoing studies of Hen Harrier ecology at UCC, researchers are examining the relationship between breeding habitat and breeding success of Hen Harriers in Ireland for the first time (Irwin et al. 2008). The aim of this research is to improve our understanding of the value of different habitats for breeding Hen Harriers. The dataset used comprised the breeding outcomes of 144 Hen Harrier nests spanning three years from 2007-2009. These nests were located in three of the areas that contributed data to the nest site selection study described earlier (North Kerry, the Slieve Aughty mountains and the Ballyhoura mountains), as well as a fourth area in West Clare, which has recently been discovered to be important for Hen Harriers. Data were collected on nest location, timing of breeding, clutch size, brood size and nest success. Previous studies have gathered such information by direct observation and systematic surveys, which are both time-consuming and difficult. The team at UCC are using these traditional methods together with novel technologies including nest cameras and GPS tracking to gain an insight into the breeding success of Hen Harriers in the four study areas; 45, 60 and 49 nests were located and monitored for breeding success in 2007, 2008 and 2009 respectively.

Preliminary analysis of results to date has revealed that breeding success is very variable both between study areas and between study years (Figure 4) (Irwin et al. 2008). The overall success rate of all nests studied was 62% in 2007, 64% in 2008 and 49% in 2009. The large drop in overall success rate in 2009 was driven by reduced success rates in the West Clare and Kerry study areas in that year. Almost 50% of all nests included in our studies were successful, fledging at least one juvenile. This is typical of reported success rates for Hen Harrier nests, where success rates of 50-70% are common in suitable habitat (Green and Etheridge 1999; Amar et al. 2007). Just 30% of nests fledged at least one young in Orkney during one study in the 1990s where low breeding success was related to habitat and to an overall decline in Hen Harrier population size.

The productivity of nests in Ireland was, however, quite low compared to that of other populations. There is a lot of variation between sites, with the Slieve Aughties being the least productive site and Kerry and West Clare being the most productive (Figure 5). It is important to note that Ireland has experienced an unusual sequence of particularly wet summers during the three field seasons to date, and results should be interpreted in this context.

In order to improve our understanding of the value of different habitats for breeding Hen Harriers, we looked at information on breeding attempt outcomes to examine the relationship between habitat and breeding success. We first investigated the influence of the habitat patch in which the nest was situated, before expanding to look at the possible

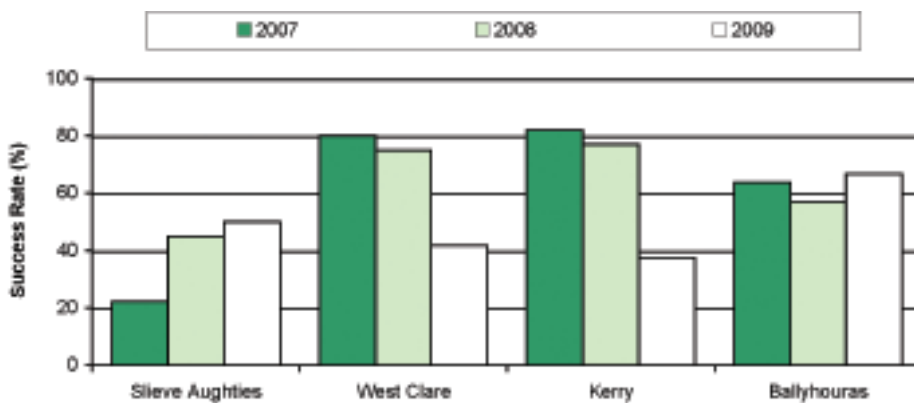


Figure 4. Breeding success (% nests successful) in each of four study areas between 2007 and 2009.



Figure 5. Productivity (number of fledglings per nesting attempt) in each of the four study areas between 2007 and 2009.

influence of forest cover in the wider landscape. As in the earlier study (Wilson et al. 2009), the most common nesting habitat in this study was second rotation pre-thicket forest (accounting for 28% of nests), followed by heath and bog (each accounting for 25% of nests). Habitat at the nest site did not explain any variation in the number of chicks fledged from successful nests, but the probability of nests fledging successfully was found to differ between nests located in second rotation forest, and those located in other habitats. Figure 6 shows that this difference is restricted to the Slieve Aughties, where nests in second rotation forest had a lower success rate than in any other combination of study site and habitat. No effect of habitat within 2 km was observed on the numbers of chicks fledged from successful

nests, but cover of second rotation forest was negatively related to nest success. Variation in second rotation cover was far greater between study sites than between failed and successful nests. However, cover of second rotation forests was lower around successful nests than around failed nests in all sites, this difference being greatest in the Slieve Aughties and in West Clare (Figure 7).

Research to date in Ireland has found that upland forested landscapes can be used by Hen Harriers. Although the relationship between Hen Harriers and forested landscapes is a complicated one, it is clear that they are capable of utilising early conifer plantations during the breeding season. In Ireland they use both afforestation and

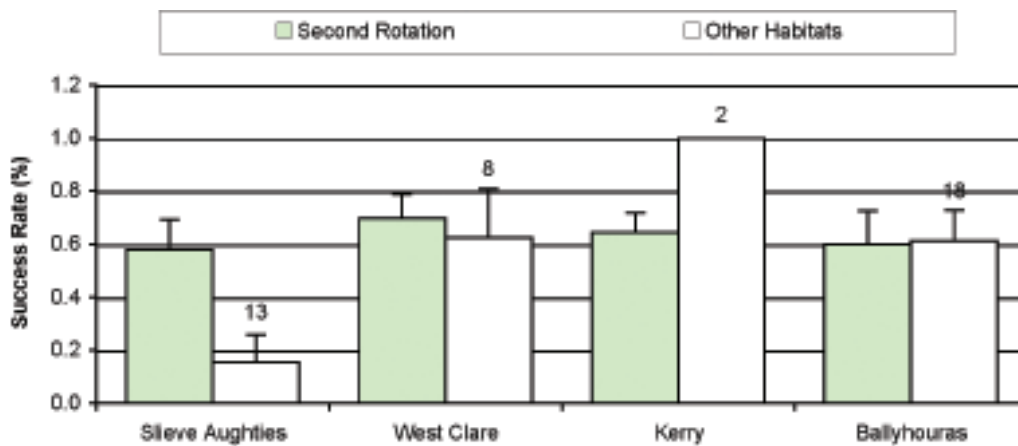


Figure 6. Mean success of nests located in second rotation pre-thicket forests and all other habitat types in each of the study areas. Values over each bar indicate the sample size.

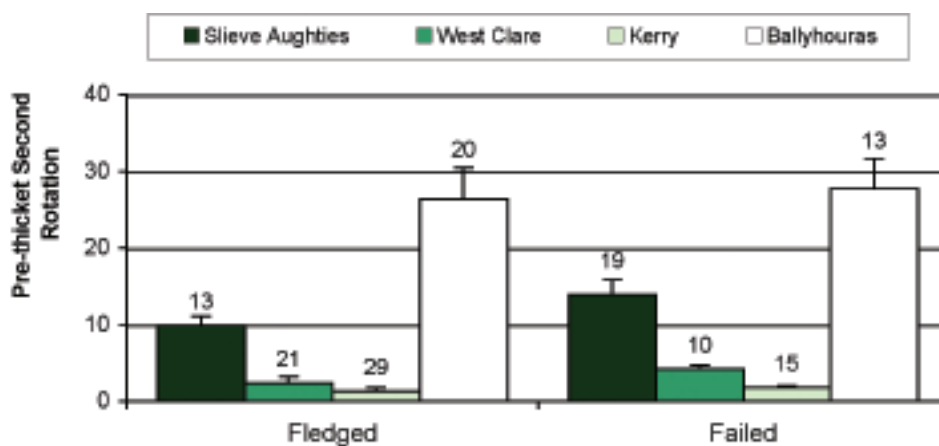


Figure 7. Mean cover of young second rotation forest within 2 km of successful and failed nests in the different study sites. Values over each bar indicate the sample size.

re-forestation sites, although the latter are useful to them for a shorter duration. Over the past three breeding seasons, Hen Harriers in the most productive sites studied in Ireland have produced enough juveniles that populations in these areas may be increasing, but in other sites it is likely that productivity is barely sufficient to sustain the number of breeding pairs. Research has found no effect of either total forest cover or closed canopy forest cover on either nest success rates or productivity. However, pre-thicket second rotation forest cover has been negatively related to nest success, both at the nest site and at a 2 km scale. Research is ongoing to determine whether these observed relationships are causal, and why they vary from one area to another. Numerous possibilities are being considered, including reduced time to canopy closure, increased risk of disturbance and persecution, and increased levels of nest predation.

Improving our understanding of the value of second rotation pre-thicket forests for breeding Hen Harriers is particularly important, partly because of their demonstrated preference for this habitat, but also because the proportion of this habitat in the forest estate will continue to increase for the foreseeable future. Commercial forests are dynamic habitats, with the proportion of young forest cover within the forested landscape continually changing due to harvesting, planting and tree growth. At the scale of an individual SPA or breeding territory, such change can have dramatic consequences for the habitats available to Hen Harriers. In addition, the Irish government currently has ambitious targets of national levels of afforestation, aiming to increase Ireland's forest cover by half over the next 20 years (COFORD 2009). In the context of these changes in Ireland's forest estate, and given the importance of forested areas for Hen Harriers, it is vital that we continue to improve our understanding of Hen Harrier breeding ecology, in particular the value of different habitats for nesting and foraging during the breeding season. Ongoing work at UCC aims to address the remaining knowledge gaps by tracking foraging male Hen Harriers using GPS technology, to investigate the influence of habitat composition around the nest on foraging and provisioning behaviour. It is also very important that we continue to monitor the breeding Hen Harrier population, in order to be able to detect whether and in what way it is affected by changes in the forest estate, or by pressures from non-forest

factors such as agricultural intensification, windfarm development and climate change.

References

- Amar, A., Arroyo, B., Meek, E., Redpath, S. and Riley, H. 2007. Influence of habitat on breeding performance of Hen Harriers *Circus cyaneus* in Orkney. *Ibis* 150: 400-404.
- Amar, A. and Redpath, S. 2005. Habitat use by Hen Harriers *Circus cyaneus* on Orkney: implications of land-use change for this declining population. *Ibis* 147: 37-47.
- Amar, A., Redpath, S. and Thirgood, S. 2003. Evidence for food limitation in the declining hen harrier population on the Orkney Islands, Scotland. *Biological Conservation* 111: 377-384.
- Arroyo, B., Leckie, F. and Redpath, S. 2006. *Habitat use and range management on priority areas for Hen Harriers*. Report to Scottish Natural Heritage, Centre for Ecology and Hydrology, Banchory, Aberdeenshire.
- Barton, C., Pollock, C., Norriss, D.W., Nagle, T., Oliver, G.A. and Newton, S. 2006. The second national survey of breeding Hen Harriers *Circus cyaneus* in Ireland. *Irish Birds* 8: 1-20.
- Bibby, C. J. and Etheridge, B. 1993. Status of the Hen Harrier *Circus cyaneus* in Scotland in 1988-1989. *Bird Study* 40: 1-11.
- Bibby, C.J., Phillips, B.N. and Seddon, J.E. 1985. Birds of restocked conifer plantations in Wales. *Journal of Applied Ecology* 22: 619-633.
- Burton, N.H.K. 2007. Influences of restock age and habitat patchiness on Tree Pipits *Anthus trivialis* breeding in Breckland pine plantations. *I* 149: 193-204.
- Butet, A. and Leroux, A.B.A. 2001. Effects of agriculture development on vole dynamics and conservation of Montagu's harrier in western French wetlands. *Biological Conservation* 100: 289-295.
- Chapman, A.D. 2009. *Numbers of Living Species in Australia and the World*. Second edition. A Report for the Australian Biological Resources Study September 2009.

- COFORD 2009. *Forestry 2030*. National Council for Forest Research and Development, Dublin.
- Ferguson-Lees, J. and Christie, D.A. 2001. *Raptors of the World*. Christopher Helm Publishers Ltd.
- Green, R.E. and Etheridge, B. 1999. Breeding success of the hen harrier *Circus cyaneus* in relation to the distribution of grouse moors and the red fox *Vulpes vulpes*. *Journal of Applied Ecology* 36: 472-483.
- Irwin, S., Wilson, M.W., Kelly, T.C., O'Donoghue, B., O'Mahony, B., Oliver, G.A., Cullen, C., O'Donoghue, T. and O'Halloran, J. 2008. A note on the breeding biology of Hen Harriers *Circus cyaneus* in Ireland. *Irish Birds* 8: 331-334.
- Lynas, P., Newton, S.F. and Robinson, J.A. 2007. The status of birds in Ireland: an analysis of conservation concern 2008-2013. *Irish Birds* 8: 149-167.
- MacGowan, F. and Doyle, G.J. 1996. *The effects of sheep grazing and trampling by tourists on lowland blanket bog in the west of Ireland*. In: Disturbance and Recovery in Ecological Systems. Giller, P. S. and Myers, A. A., Royal Irish Academy, Dublin.
- MacWhirter, R.B. and Bildstein, K.L. 1996. *Northern Harrier (Circus cyaneus)*. In: The Birds of North America. Poole, A. and Gill, F., The Academy of Natural Sciences, Pennsylvania and The American Ornithologists' Union, Washington.
- Madders, M. 2000. Habitat selection and foraging success of Hen Harriers *Circus cyaneus* in west Scotland. *Bird Study* 47: 32-40.
- Madders, M. 2003. *A model of Hen Harrier ranging behaviour*. In: Birds of prey in a changing environment Thompson, D.B.A., Redpath, S., Fielding, A.H., Marquiss, M. and Galbraith, C.A., The Stationery Office, Edinburgh.
- McKee, A.-M., Bleasdale, A. and Skeffington, M.S. 1998. *The effect of different grazing pressures on the above-ground biomass of vegetation in the Connemara uplands*. In: Towards a Conservation Strategy for the Bogs of Ireland. O'Leary, G. and Gormley, F., Irish Peatland Council, Dublin.
- Norriss, D.W., Marsh, J., McMahon, D. and Oliver, G.A. 2002. A national survey of breeding Hen Harriers *Circus cyaneus* in Ireland 1998-2000. *Irish Birds* 7: 1-10.
- O'Donoghue, B. 2004. *The Hen Harrier in Ireland*. Masters Thesis, University College Dublin.
- O'Flynn, W.J. 1983. Population changes of the Hen Harrier in Ireland. *Irish Birds* 2: 337-343.
- Petty, S.J. and Anderson, D. 1986. Breeding by Hen Harriers *Circus cyaneus* on restocked sites in upland forests. *Bird Study* 33: 177-178.
- Picozzi, N. 1978. Dispersion, breeding and prey of the hen harrier *Circus cyaneus* in Glen Dye, Kincardineshire. *Ibis* 120: 498-509.
- Redpath, S., Amar, A., Madders, M., Leckie, F. and Thirgood, S. 2002. Hen harrier foraging success in relation to land use in Scotland. *Animal Conservation* 5: 113-118.
- Redpath, S., Madders, M., Donnelly, E., Anderson, B., Thirgood, S., Martin, A. and McLeod, D. 1998. Nest site selection by Hen Harriers in Scotland. *Bird Study* 45: 51-61.
- Serrentine, P. 1992. *Northern harrier, Circus Cyaneus*. In: Migratory nongame birds of management concern in the Northeast. Schneider, K.J. and Pence, D.M., US Fish and Wildlife Service, Newton Corner, Massachusetts.
- Sim, I.M.W., Dillon, I.A., Eaton, M.A., Etheridge, B., Lindley, P., Riley, H., Saunders, R., Sharpe, C. and Tickner, M. 2007. Status of the Hen Harrier *Circus cyaneus* in the UK and Isle of Man in 2004, and a comparison with the 1988/89 and 1998 surveys. *Bird Study* 54: 256-267.
- Sim, I.M.W., Gibbons, D., Bainbridge, I.P. and Mattingley, W.A. 2001. Status of the Hen Harrier *Circus cyaneus* in the UK and Isle of Man in 1998. *Bird Study* 48: 341-353.
- Sinha, P.C. 1998. *Biodiversity Depletion (Encyclopaedia of Sustainable Development)*. Anmol Publications Pvt Ltd.

- Thirgood, S., Redpath, S. and Graham, I.M. 2003. What determines the foraging distribution of raptors on heather moorland? *Oikos* 100: 15-24.
- Truscott, A.M., Mitchell, R.J., Palmer, S.C.F. and Welch, D. 2004. The expansion of native oakwoods into conifer cleared areas through planting. *Forest Ecology and Management* 193: 335-343.
- Vanhinsbergh, D.P. and Chamberlain, D.E. 2001. Habitat associations of breeding Meadow Pipits *Anthus pratensis* in the British uplands. *Bird Study* 148: 159-172.
- Watson, D. 1977. *The Hen Harrier*. T. and A.D. Poyser.
- Wilson, M.W., Gittings, T., O'Halloran, J., Kelly, T.C. and Pithon, J. 2006. *The distribution of Hen Harriers in Ireland in relation land use cover, particularly forest cover*. COFORD Connects Note, Dublin.
- Wilson, M.W., Irwin, S., Norriss, D.W., Newton, S.F., Collins, K., Kelly, T.C. and O'Halloran, J. 2009. The importance of pre-thicket conifer plantations for nesting Hen Harriers *Circus cyaneus* in Ireland. *Ibis* 151: 332-343.