The effects of fieldwork on Hen Harrier *Circus cyaneus* breeding success

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While information on the ecology of endangered species is essential to inform conservation measures, the acquisition of the necessary scientific data during the breeding season involves field methods that could potentially have a negative impact on the study species. Studies of the impact of fieldwork on the breeding success of endangered species make an important contribution to the development of field methodologies that have a minimal impact on species and ecosystems. Hen Harriers *Circus cyaneus* are one of the most vulnerable bird species in Ireland at present and also act as a flagship species of upland habitats, which are under considerable pressure from human activities. In this study, which used data from five breeding seasons, we investigated the effects of nest visits for the purpose of data collection on the breeding success of Hen Harriers. Success rates were compared between groups of nests at which different types of fieldwork were carried out, including: remote observations only (no visits); nest visits; and nest visits with camera deployment. No negative effect of nest visits on breeding success was observed. At visited nests, the additional deployment of nest cameras had no apparent effect on nesting success. These findings show that fieldwork during this study did not have a negative impact on overall Hen Harrier breeding success. The absence of a negative effect of fieldwork should be considered in the context of the study, which involved highly trained, experienced staff adhering to detailed fieldwork protocols that ensured that the welfare of birds and their nests was the main priority.

Introduction

Data collected on different aspects of the ecology of endangered species are essential to improve our knowledge of these species' ecological requirements and to inform effective conservation actions (Bird & Bildstein 2007, Hardey *et al.* 2013). However, data collection in these studies may sometimes involve field methods that could potentially have a negative impact on the species under study, particularly as they are conducted during the breeding season (Fletcher *et al.* 2005, Rosenfield *et al.* 2007). The conservation of these vulnerable species and the ethical issues of environmental research and data collection must be given due consideration

Plate 234. Hen Harrier (Richard T. Mills).

in the design of ecological fieldwork. In this context, research on the impact of these studies themselves on the study species are invaluable so that scientists can ensure that their research does not have a negative impact on species or ecosystems (Costello *et al.* 2016).

Hen Harriers *Circus cyaneus* are birds of particular conservation concern in Ireland (Colhoun & Cummins 2013) and throughout much of their range (Burfield & von Bommel 2004). Under the EU Birds Directive all member states are required to take measures to ensure the survival of Hen Harriers at a favourable conservation status. The advancement of scientific knowledge and the development of effective conservation management plans rely on relevant, up-to-date, evidence-based scientific research (Bird & Bildstein 2007, Lerner 2009), which in turn rely on data collected in the Hen Harrier's natural habitat (Irwin *et al.* 2008, 2011). In this way, research will yield results that are directly relevant to the welfare and conservation of this species (Bird & Bildstein 2007, Ibáñez-Álamo *et al.* 2012). It is important that the fieldwork carried out to collect these data impacts minimally on the fitness of individual birds and on the viability and conservation status of Hen Harrier populations. To this end, negative impacts on breeding success must be avoided (Rosenfield *et al.* 2007, Hardey *et al.* 2013).

The collection of data on Hen Harrier breeding biology involves locating nest sites to gather data on breeding success. One or more visits may be required over the course of a breeding season to determine the basic information on breeding biology and productivity, and to determine the outcome of the breeding attempt (Bird & Bildstein 2007, Lerner 2009, Hardey *et al.* 2013). Much attention has been paid by ornithological researchers to the potential for their activities to negatively impact on their study species (Willis 1973, Major 1990, Götmark 1992, Fair *et al.* 2010, Uher-Koch *et al.* 2015, Smallwood 2016). Despite some variation both between and within species in how individuals respond to nest visits (Fair *et al.* 2010), raptors as a group are less susceptible to disturbance associated with research activity than many other bird groups (Götmark 1992). Evidence suggests that nest visits for research purposes do not negatively impact on the nest survival of a number of species investigated (Ibáñez-Álamo *et al.* 2012), particularly where nests visits are infrequent (MacIvor *et al.* 1990, Major 1990, Fletcher *et al.* 2005, Fair *et al.* 2010). However, no studies have yet been undertaken specifically on Hen Harriers.

However, there are a number of ways in which the activities of researchers involved in data collection during the breeding season could have adverse impacts. Possible impacts include nest desertion, egg or chick mortality, premature fledging, increased predation risk, decreased nest attendance and injury to handled birds, all of which can negatively impact on breeding success (Blackmer *et al.* 2004, Fletcher *et al.* 2005, Rosenfield *et al.* 2007, Ibáñez-Álamo *et al.* 2012). Increased predation risk is a particularly important consideration when working with ground nesting birds such as the Hen Harrier (Willis 1973, Major 1990, Hannon *et al.* 1993). Given the vulnerable status of Hen Harriers across their range, and the continued need for fieldwork on this species, it is important to gather information specific to this species in order that the need for further research can be balanced with ensuring that disturbance pressures on its small and declining population are minimized.

In order to ensure that sufficient data are collected from nests while minimizing the number of nest visits, several researchers have opted to use nest cameras to record breeding biology and predator data (Bolton *et al.* 2007). Nest cameras have been associated with both negative (Pietz & Granfors 2000) and positive (Herranz *et al.* 2002) impacts on nest success through their effect on nest predation rates (Richardson *et al.* 2009, Humphreys *et al.* 2012). Therefore, to minimize negative impacts of fieldwork on the survival or reproductive success of avian study populations, we must evaluate the effects of fieldwork on nest survival. This study set out to examine the effect of fieldwork on the breeding ecology of Hen Harriers. These data were collected as part of a larger, long-term study investigating optimum scenarios for Hen Harrier conservation in Ireland (Irwin *et al.* 2012). This project involved visits to nests by fieldworkers under license over a five-year period, during which information was collected on breeding biology, foraging behaviour and nestling development. In order to facilitate data collection, cameras were deployed at a subset of nests. This study investigates the effects of nest visits on the breeding success of Hen Harriers by comparing the success of visited and unvisited nests.

Methods

As part of a five-year study on Hen Harrier conservation in Ireland (Irwin *et al.* 2008, 2011, Wilson *et al.* 2009, 2010, 2012), data on breeding Hen Harriers were collected at four study sites (Slieve Aughty Mountains, West Clare, Kerry and Ballyhoura Mountains) in the south of Ireland between 2007 and 2011. During this time 173 nests were monitored in order to collect information on breeding ecology, including first egg-laying and fledging dates, clutch size, brood size, nest success and productivity. Nest visits were undertaken at a subset of these nests (under license from National Parks and Wildlife Service) to gather breeding biology data where appropriate. The success of all visited nests was recorded, and unvisited nests were recorded as successful where recently-fledged juveniles were observed flying in the nesting area (Watson 1977). Wherever possible, stage of failure at unvisited nests was determined during a post-failure nest visit.

Nests that were least vulnerable to disturbance associated with visits and that were the most accessible in terms of fieldwork logistics were selected for nest visits (n = 103) and all other nests were monitored from a distance (n = 70). Before deciding whether or not to visit each nest, we assessed the risks to that nest deriving from inherent vulnerability of the nest to discovery by humans or predators and the potential effects of visits on nest success. Risk in the former category was assessed in relation to distance from the nearest path, track or road, level of human activity along this path, visibility from this route, and ease of access. Fieldwork-related risk was assessed according to distance from the nearest route, human activity along this route, conspicuousness of observation points, reaction of adult birds to fieldworkers, and the degree to which ease of access to the nest was altered by fieldworker activity. Where any of these factors were deemed to pose a high risk to nest success, the nests were not visited. Where nests were deemed suitable for visits based on these criteria, only those that were suitable in terms of fieldwork logistics were selected. The factors considered in this assessment were costs in terms of fieldwork time and ease of access to the nests, with difficult terrain and long cable runs being avoided.

Nests selected for visits were visited between one and four times while they were active. Nests were not visited until one week after incubation had begun in order to be certain that egg-laying was complete. This was determined by the behaviour of the female following food-passes (Hardey *et al.* 2013). The first visit to a nest was made only when we were confident that the nest location had been identified to within an accuracy of about 10 m. Nest visits were typically made by two or three people, one of these acting as a distant observer using a telescope and hand-held radio to guide the others to the location of the nest. However, in situations where the location of the nest was readily identifiable 'on the ground', nest visits were sometimes made by a single, unaccompanied fieldworker.

The first priority during fieldwork was the welfare of the birds, and every effort was made to avoid distress or loss of the nest as a result of visits. Fieldworkers stayed at nests no longer than was necessary to carry out the required actions. On first visiting a nest, fieldworkers recorded its position using a GPS, and took a photograph of the nest contents. At 25 nests, discreet 'bullet' cameras were deployed (see Irwin *et al.* (2012) for methodological details) to record activity at the nest. Real-time footage of the nest could be viewed at a base station 50-300 m away. Camera deployment precluded the need for further visits to assess progress of the clutch or brood. Visits to nests containing eggs or young chicks were not made in wet or cold weather or during the early morning, to ensure that any temporary avoidance of the nest by the female during and after the visit did not expose the nest contents to inclement conditions. After visiting a nest, observers attempted to replace any vegetation disturbed on approach to ensure that access to the nest was no easier than prior to the visit.

Statistical analyses were carried out in R version 2.13.1 (R Core Project Development). Binomial generalized linear models (GLMs) with logistic-exposure link function (Schaffer 2004) were carried out using the GLM function in the MASS package. This technique allows for testing of the effects of fieldwork activities on nest success (the probability of nests successfully fledging at least one chick) while controlling for the number of observation days at each nest (Schaffer 2004). As well as the two research-related variables 'visited' and 'camera', we also tested for effects of 'year' and 'region' on nest success using GLM. Final models were selected by backwards selection performed from fully specified models including all explanatory variables, until no terms could be removed from the model without incurring an increase in AIC (Akaike's Information Criterion). Statistically significant differences between levels of factors with more than two levels were identified using Tukey post-hoc comparison tests, carried out using the GLHT function in the Multcomp package.

Results

Of a total of 173 nests monitored across the four study areas between 2007 and 2011, 103 were visited and 70 were monitored from a distance. Of the 103 nests that were visited, 66 fledged young successfully and 37 failed to fledge any young. Fifteen of the 25 nests where cameras were deployed fledged young successfully while ten failed to fledge any young. Of the 70 nests that were not visited, 27 fledged young successfully and 43 failed to fledge any young. Among all failed nests (80), 23 failed during egg-laying or incubation, 41 failed at the chick stage, and 16 nests (all unvisited) failed at an indeterminate stage.

In a model describing the fledging success of all 173 nests (103 visited, 70 unvisited) monitored during this project, visit status and study area were both retained in the final model with year being excluded (Table 1). Post-hoc tests showed that success of nests was higher in West Clare than in the Slieve Aughty Mountains ($z = 3.15$, $P = 0.001$) and higher at visited than at unvisited nests ($z = 3.85$, $P = 0.0001$). Nest success was significantly higher at visited nests than at nests where no visits were carried out. In order to control for biases related to nests failing before they could be visited, we conducted the analyses again using only the 136 nests (91 visited and 45 unvisited) that had survived beyond hatching. This revealed that the effect of nest visits on nest survival was marginally non-significant in this case. In common with the model of all 173 nests, the final model retained study area and nest visits

(Table 2), with inter-study area differences lying principally between Area 1 (Slieve Aughty Mountains) and Area 4 (West Clare) ($z = 2.35_{1,56}$, $P = 0.019$). However, the apparent positive influence of nest visits was greatly diminished and marginally non-significant ($z = 1.85_{1,134}$, $P = 0.064$).

In order to investigate the effect of camera deployment, a model describing the fledging success of 103 visited nests (25 with cameras, 78 without) revealed no difference in fledging success between nests with and without cameras. The only term retained in the final model was study area (Table 3). Post-hoc tests showed that success of nests was lower in the Slieve Aughty Mountains than in the Ballyhoura Mountains ($z = 2.70_{1,62}$, $P = 0.007$), Kerry ($z = 2.90_{1,54}$, $P = 0.004$) and West Clare ($z = 2.74_{1,43}$, $P = 0.006$).

Table 1. Summary of a binomial generalized linear model (GLM) describing the apparent effects of study area and nest visits on nest success of 173 Hen Harrier nests*.

Variable	Estimate	SE	*z* value	*P*
Intercept	2.89	0.29	9.91	< 0.0001
Area 2 (Ballyhoura)	0.71	0.34	2.08	0.04
Area 3 (Kerry)	0.53	0.33	1.63	0.10
Area 4 (West Clare)	1.37	0.43	3.15	0.001
Visited	1.00	0.26	3.85	0.0001

*The fully specified model included year, as well as the two factors retained in the final model, study area and nest visits. The effects of one level of each factor (Area1, being the Slieve Aughty Mountains; and Unvisited) are included in the intercept of the model. Null deviance = 238.9_{172}, residual deviance = 255.7_{163}, AIC = 268.6.

Table 2. Summary of a binomial generalized linear model (GLM) describing the apparent effects of study area and nest visits on nest success of 136 Hen Harrier nests that survived beyond hatching*.

Variable	Estimate	SE	*z* value	*P*
Intercept	3.62	0.37	9.84	< 0.0001
Area 2 (Ballyhoura)	0.65	0.42	1.55	0.12
Area 3 (Kerry)	0.65	0.42	1.53	0.13
Area 4 (West Clare)	1.29	0.55	2.35	0.019
Visited	0.63	0.34	1.85	0.064

*The fully specified model included year, as well as the two factors retained in the final model, study area and nest visits. The effects of one level of each factor (Area1, being the Slieve Aughty Mountains; and Unvisited) are included in the intercept of the model. Null deviance = 167.4_{134}, residual deviance = 171.0_{130}, AIC = 181.0.

Table 3. Summary of a binomial generalized linear model (GLM) describing the apparent effects of study area and nest visits on nest success of 103 visited Hen Harrier nests*.

Variable	Estimate	SE	*z* value	*P*
Intercept	3.50	0.27	12.93	< 0.0001
Area 2 (Ballyhoura)	1.10	0.41	2.70	0.007
Area 3 (Kerry)	1.43	0.50	2.90	0.004
Area 4 (West Clare)	2.84	1.04	2.74	0.006

*The fully specified model included year and camera deployment, as well as study area, the only variable included in the final model. The effects of Area1 (Slieve Aughty Mountains) are included in the intercept of the model. Null deviance = 135.5_{102}, residual deviance = 144.8_{99}, AIC = 152.8.

Discussion

The output from our nest success model, including failures at all stages, suggests that breeding success at Hen Harrier nests was not negatively affected by nest visits. Although breeding success was slightly higher at nests that were visited than at nests that were not visited, the observed difference in breeding success was greatly diminished when only nests that survived beyond hatching were considered. This indicates that the apparently higher success of visited nests was due in large part to the fact that many of the nests that failed during laying and incubation did so before it was possible for us to visit them. After nests had been located, fieldworkers did not visit them until they were satisfied that females at these nests had started incubating, in order to minimize the risk of nest abandonment (Dickinson *et al.* 1987, Craik & Titman 2009, Hardey *et al.* 2013). If nests failed during this time, they were unavailable for visits, resulting in the observed bias in the comparison of success rates between visited and unvisited nests.

By conducting the analysis using only nests that had survived beyond hatching we considered only nests that were old enough to be visited, thereby greatly diminishing the potential for failure before nests were visited, and biasing our assessments. However, visited nests still had a slightly higher rate of survival than unvisited nests, though this difference was not statistically significant. It is possible that at some nests with chicks visits were delayed due to uncertainty of nest stage. However, this is unlikely to have been the case at many nests, as the majority (50 out of 61) of nests that were visited when they had chicks were originally discovered before hatching. Furthermore, changes in female behaviour make it possible to determine when Hen Harrier clutches have hatched, making it unnecessary for fieldworkers to delay the first visit to a nest.

It is also likely that our strict criteria for selecting nests for fieldwork resulted in our not visiting the nests that were most vulnerable, and which may have been either positively or negatively affected by disturbance, and our findings are presented in this context. While an ideal experimental design would have been to randomly assign nests to each of the categories, this is not possible with scarce and vulnerable bird species. We also cannot rule out the possibility that nest visits may, in some instances, have a positive effect on survival. Positive effects of nest visits on rates of nest success have been previously described in several studies (Leighton *et al.* 2010, Ibáñez-Álamo *et al.* 2012). Such effects appear to be most commonly realized through avoidance of, or reduced activity in, nest areas by predators in response to fieldworker presence and activity.

Among visited nests in this study, we found no difference in breeding success between nests with and without nest-cameras. Previous reviews of daily nest survival rates at nests with and without cameras have shown that, on balance, cameras may have a positive effect on survival by acting as a deterrent to potential nest predators (Richardson *et al.* 2009). This may occur where predators associate signs of human activity with danger and therefore avoid the nest (Picman & Schriml 1994). However, our findings indicate that the deployment of discreet 'bullet' cameras at Hen Harriers nests did not significantly affect predation rates either positively or negatively. This suggests that data on nest survival rates collected from nests using cameras may be directly comparable to data collected using alternative methods, which is a concern in the interpretation of camera-derived data (Bolton *et al.* 2007).

In this five-year study of possible effects of nest visits and nest camera deployment we found no measurable disturbance effect of research activity across the island of Ireland on Hen Harrier breeding outcomes. The absence of a negative effect of fieldwork should be considered in the context of the study, which involved highly trained, experienced staff adhering to carefully devised fieldwork protocols that ensured that the welfare of birds and their nests was the main priority, and every effort was made to minimize disturbance associated with research activity. The implications of our findings are that, if nests are selected appropriately and fieldwork methods are strictly standardized to minimize negative effects, Hen Harriers in Ireland are sufficiently robust to disturbance to allow visits to nests without noticeable negative impacts on their breeding success. Previous work on other ground-nesting species has arrived at similar conclusions (O'Grady *et al.* 1995, Lloyd *et al.* 2000, Verboven *et al.* 2001, Ibáñez-Álamo *et al.* 2012). Regulators of fieldwork on protected species such as Hen Harriers should be careful to minimize risks to these species. This will require weighing the likelihood of negative impacts on individuals resulting from fieldwork against the potential for positive effects on the wider population due to information that can be used to improve conservation management strategies.

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References

Bird, D.M. & Bildstein, K.L. 2007. *Raptor Research and Management Techniques.* Hancock House Publishers, Surrey, British Columbia.

Blackmer, A.L., Ackerman, J.T. & Nevitt, G.A. 2004. Effects of investigator disturbance on hatching success and nest-site fidelity in a long-lived seabird, Leach's Storm-petrel. *Biological Conservation* 116: 141-148.

Bolton, M., Butcher, N., Sharpe, F., Stevens, D. & Fisher, G. 2007. Remote monitoring of nests using digital camera technology. *Journal of Field Ornithology* 78: 213-220.

Burfield, I. & von Bommel, F. 2004. *Birds in Europe: population estimates, trends and conservation status.* Conservation Series No. 12. BirdLife International, Cambridge.

Colhoun, K. & Cummins, S. 2013. Birds of Conservation Concern in Ireland. *Irish Birds* 9: 523-544.

Costello, M., Beard, K.H., Corlett, R.T., Cumming, G.S., Devictor, V., Loyola, R., Maas, B., Miller-Rushing, A.J., Pakeman, R. & Primack, R.B. 2016. Field work ethics in biological research. *Biological Conservation* 203: 268-271.

Craik, S.R. & Titman, R.D. 2009. Nesting ecology of Red-breasted Mergansers in a Common Tern colony in Eastern New Brunswick. *Waterbirds* 32: 282-292.

Dickinson, T.E., Falls, J.B. & Kopachena, J. 1987. Effects of female pairing status and timing of breeding on nesting productivity in Western Meadowlarks *(Sturnella neglecta). Canadian Journal of Zoology* 65: 3093-3101.

Fair, J.M., Paul, E. & Jones, J. 2010. *Guidelines to the use of Wild Birds in Research.* Third edition. Ornithological Council, Washington, D.C.

Fletcher, K., Warren, P. & Baines, D. 2005. Impact of nest visits by human observers on hatching success in Lapwings *Vanellus vanellus:* a field experiment. *Bird Study* 52: 221-223.

Götmark, F. 1992. The effects of investigator disturbance on nesting birds. *Current Ornithology* 9: 63-104.

Hannon, S.J., Martin, K., Thomas, L. & Schleck, J. 1993. Investigator disturbance and clutch predatin in Willow Ptarmigan: methods for evaluating impact. *Journal of Field Ornithology* 64: 575-586.

Hardey, J., Crick, H., Wernham, C., Riley, H., Etheridge, B. & Thompson, D.B.A. 2013. *Raptors: a field guide for surveys and monitoring.* Stationery Office, Edinburgh.

Herranz, J., Yanes, M. & Suárez, F. 2002. Does photo-monitoring affect nest predation? *Journal of Field Ornithology* 73: 97-101.

Humphreys, E.M., Gilbert, L., Furness, R.W., Littlewood, N., Mitchell, R., Pakeman, R., Fuller, R.J. & Calladine, J. 2012. *Scoping Report to Uist Wader Research: suggested research programme 2012–2014.* Scottish Natural Heritage Commissioned Report.

Ibáñez-Álamo, J.D., Sanllorente, O. & Soler, M. 2012. The impact of researcher disturbhance on nest predation rates: a meta-analysis. *Ibis* 154: 5-14.

Irwin, S., Wilson, M.W., Kelly, T.C., O'Donoghue, B., O'Mahony, B., Oliver, G.A., Cullen, C., O'Donoghue, T. & O'Halloran, J. 2008. A note on the breeding biology of Hen Harriers *Circus cyaneus* in Ireland. *Irish Birds* 8: 331-334.

Irwin, S., Wilson, M.W., Kelly, T.C., O'Mahony, B., Oliver, G.A., Troake, P., Ryan, B., Cullen, C., O'Donoghue, B. & O'Halloran, J. 2011. The breeding biology of Hen Harriers *Circus cyaneus* in Ireland over a five year period. *Irish Birds* 9: 165-172.

Irwin, S., Wilson, M.W., O'Donoghue, B., O'Mahony, B., Kelly, T.C. & O'Halloran, J. 2012. *Optimum scenarios for Hen Harrier conservation in Ireland.* Report prepared for the Department of Agriculture, Food & the Marine, Dublin.

Leighton, P.A., Jorrocks, J.A. & Kramer, D.L. 2010. Conservation and the scarecrow effect: can human activity benefit threatened species by displacing predators? *Biological Conservation* 143: 2156-2163.

Lerner, H.R. 2009. Raptor research and management techniques. *Wilson Journal of Ornithology* 121: 222-224.

Lloyd, P., Little, R.M. & Crowe, T.M. 2000. Investigator effects on the nesting success of arid-zone birds. *Journal of Field Ornithology* 71: 227-235.

MacIvor, L.H., Melvin, S.M. & Griffin, C.R. 1990. Effects of research activity on Piping Plover nest predation. *Journal of Wildlife Management* 54: 443-447.

Major, R.E. 1990. The effect of human observers on the intensity of nest predation. *Ibis* 132: 608-612.

O'Grady, D.R., Hill, D.P. & Barclay, R.M.R. 1995. Nest visitation by humans does not increase predation on Chestnut-collared Longspur eggs and young. *Journal of Field Ornithology* 67: 275-280.

Picman, J. & Schriml, L.M. 1994. A camera study of temporal patterns of nest predation in different habitats. *Wilson Bulletin* 106: 456-465.

Pietz, P.J. & Granfors, D.A. 2000. Identifying predators and fates of grassland passerine nests using miniature video cameras. *Journal of Wildlife Management* 64: 71-87.

Richardson, T.W., Gardali, T. & Jenkins, S.H. 2009. Review and meta-analysis of camera effects on avian nest success. *Journal of Wildlife Management* 73: 287-293.

Rosenfield, R.N., Grier, J.W. & Fyfe, R.W. 2007. Reducing management and research disturbance. In Bird, D.M. & Bildstein, K.L. (eds). *Raptor Research and Management Techniques.* pp. 351-364. Hancock House Publishers, Surrey, British Columbia.

Schaffer, T.L. 2004. A unified approach to analyzing nest success. *Auk* 121: 526-540.

Smallwood, J.A. 2016. Effects of researcher-induced disturbance on American Kestrels breeding in nest boxes in northwestern New Jersey. *Journal of Raptor Research* 50: 54-59.

Uher-Koch, B.D., Schmutz, J.A. & Wright, K.G. 2015. Nest visits and capture events affect breeding success of Yellow-billed and Pacific Loons. *Condor* 117: 121-129.

Verboven, N., Ens, B.J. & Dechesne, S. 2001. Effect of investigator disturbance on nest attendance and egg predation in Eurasian Oystercatchers. *Auk* 118: 503-508.

Watson, D. 1977. *The Hen Harrier.* Poyser, Berkhamsted.

Willis, E.O. 1973. Survival rates for visited and unvisited nests of Bicolored Antbirds. *Auk* 90: 263-267.

Wilson, M.W., Irwin, S., Norriss, D.W., Newton, S.F., Collins, K., Kelly, T.C. & O'Halloran, J. 2009. The importance of pre-thicket conifer plantations for nesting Hen Harriers *Circus cyaneus* in Ireland. *Ibis* 151: 332-343.

Wilson, M.W., Irwin, S., O'Donoghue, B., Kelly, T.C. & O'Halloran, J. 2010. The use of forested landscapes by Hen Harriers in Ireland. COFORD Connects. Environment No. 10. Coford, Dublin.

Wilson, M.W., O'Donoghue, B., O'Mahony, B., Cullen, C., O'Donoghue, T., Oliver, G., Ryan, B., Troake, P., Irwin, S., Kelly, T.C., Rotella, J.J. & O'Halloran, J. 2012. Mismatches between breeding success and habitat preferenes in Hen Harriers *Circus cyaneus* breeding in forested landscapes. *Ibis* 154: 578-589.