Plate xx. Caption. © *Laurie Campbell*

Hen Harriers on Skye, 2000–12: nest failures and predation

R.L. McMillan

Hen Harrier nesting success was studied on Skye from 2000 to 2012, during which period there were 88 breeding attempts, 47 of which resulted in nest failures, with predation the most likely cause. To obtain more accurate information on predation at Hen Harrier nests, four cameras were used at nests between 2009 and 2012. Evidence from these cameras and post-mortem examinations showed that predation by Red Foxes was the commonest cause of nest failure, 65% of failures being attributed to foxes. In 75% of cases predation took place after dark. Foxes killed two incubating adult females on the nest. Foxes mainly predated young from two to four weeks old, but as recently fledged young return to the nest site to roost, they are also at risk. As fledglings increased in size, nest sites became more detectable by foxes. In the absence of nest camera evidence, it was often impossible to attribute a cause of failure, as no conclusive evidence was left at the nest site. In one instance, foxes visited nest sites over a period of up to 10 days until all the young were removed. At another site an adult fox brought cubs to a nest when small young were removed. There was little evidence that adult Hen Harriers can successfully defend their young against an incursion by a fox either in daylight or darkness.

Introduction

The Hen Harrier *Circus cyaneus* is a Scottish Biodiversity List Species and meets criterion 3a of the Species Action Framework as a threatened species which is a focus of conflicts of interest with stakeholders with other objectives notably game management. It is included in the statutory list of the UK Biodiversity Action Plan. The Hen Harrier Conservation Framework (Fielding *et al.* 2011) considered eight factors potentially affecting their distribution. Constraints ranged from grazing pressure which might reduce the heathery habitat important for prey species, to wind farms. Illegal persecution was a significant constraint in some areas, whilst in others, shortage of prey and suitable nesting habitat were identified. Predation by mammals such as foxes, and avian predators such as crows, was identified as a possible constraint on breeding success.

Hen Harriers have been studied on Skye, Highland, since 2000 where breeding sites have mainly been associated with forestry plantations. Although persecution is a significant problem in some parts of the UK, during the course of this Skye study, there was only one known instance of human interference. This paper concentrates on nest failure rates and predation by Red Fox *Vulpes vulpes*. Unlike other islands in the Hebrides, the fox is well distributed on Skye (Scott 2011).

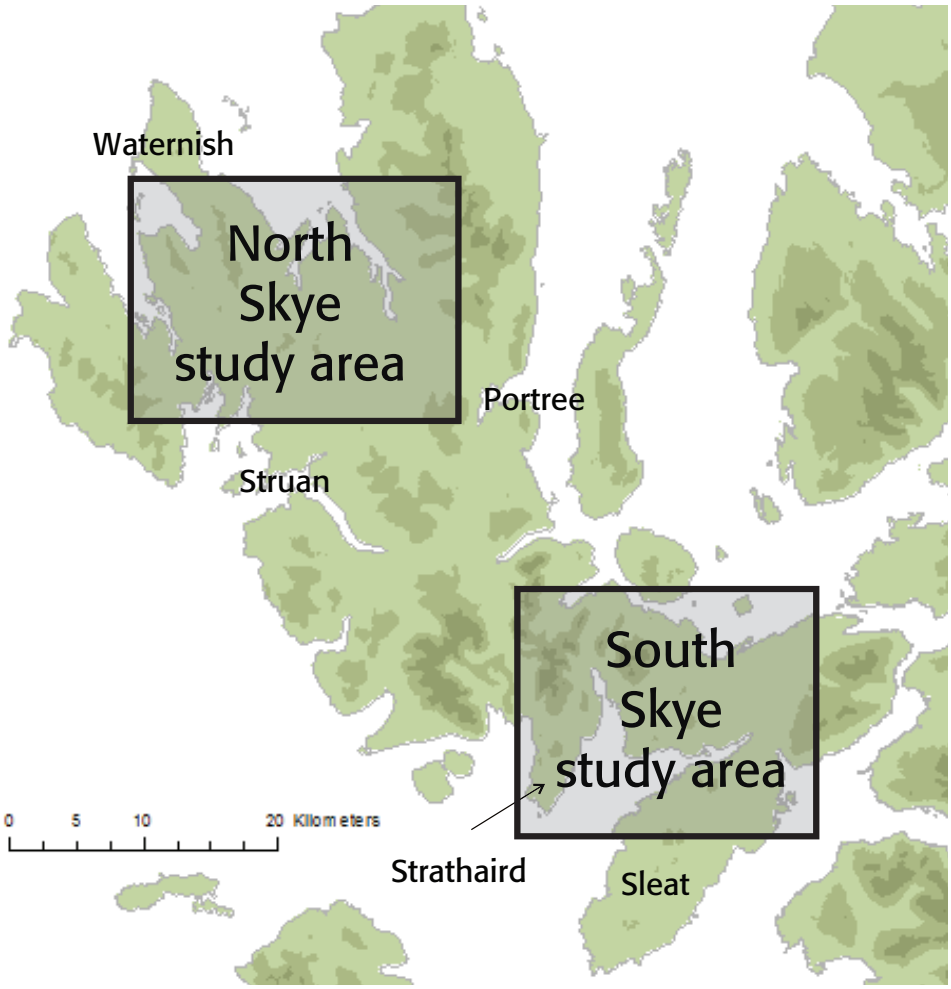

Figure 1. The Hen Harrier study areas on Skye, 2000–12.

Study area

When the study commenced in 2000 all the known breeding sites were located in the Sleat and Strathaird areas of south Skye, but the last of these was successful in 2004. Harriers were also known to nest in north-central Skye and from 2005 a study area evolved, eventually extending to 15,000 ha, lying north of the B885 Portree-Struan road and extending to Waternish. As in the south, the North Skye study area was associated with forestry plantations and moorlands immediately adjacent. Both study areas are shown in Figure1.

Methods

Fieldwork was conducted under licence issued by Scottish Natural Heritage (SNH) and followed current 'best practice' guidelines (Hardey *et al.* 2009), which recommend a minimum of four visits to territories to check site occupancy, to locate nests early in incubation, to check for young, and to check for fledged young.

Green & Etheridge (1999) acknowledged the high risk of predation to this ground nesting species and emphasised the importance of observing and counting young in flight before determining fledging success. Hardey *et al.* (2009), Whitfield & Fielding (2009) and Baines & Richardson (2013) all provide examples of evidence found at nest sites which could allow causes of failure to be determined. Attributing causes of failure can be extremely challenging, and not all types of evidence found can be described as conclusive. A thorough search of nest surrounds was carried out for evidential traces when a nest failure was discovered. However, with many nest failures there was no conclusive evidence of causal factors.

In 2008, a successful grant application was made to SNH for nest site cameras in respect of an action "which improves, protects and manages native species and habitats". Four nest site cameras were purchased from the RSPB Technical Department. Nigel Butcher of the RSPB provided training and support; for further information on the technology see Bolton *et al.* (2007). Nest site cameras were used at selected sites between 2009 and 2012.

Results

2005–08

Hen Harriers had been monitored on Skye for nine years from 2000 to 2008. The mean failure rate of nests was 51% (Table 1). Looking exclusively at the North Skye data from 2005 to 2008, the failure rate was higher at 62%. The percentage failure rate peaked at 80% in 2006, when from the five pairs which laid eggs, 22 young hatched. Two broods failed at less than two weeks and another two failed at greater than two weeks, the latter suspected by fox predation, and only two young fledged. Failure rates in the next two years remained high and there was growing concern that predation by foxes was the main cause of failure (see Fig 2). However, the evidence was weak, as it was often impossible to attribute causes.

Plate 2. Evidence of Red Fox predation of Hen Harrier chick, with bitten and chewed feathers in quill, Skye, August 2008. © *R. McMillan*

Table 1. Summary of Hen Harrier breeding success, all Skye, 2000–08.

Year	Active territories	Nests	Mean clutch size	Total young hatched	Total young fledged	Mean fledged per nest	Failed with eggs	Failed with young	Total nests failed	Cause of failure
2000	4	4	3.7	12	11	2.75	0	1	1	Predator
2001	3	3	3.7	5	5	1.66	1	0	1	Unknown
2002	5	3	2	2	2	0.66	1	1	2	Predator Unknown
2003	8	7	?	?	8	1.12	3	1	4	Predator Unknown
2004	8	8	?	?	20	2.5	2	0	2	Unknown
2005	10	9	5.4	21	16	1.8	1	2	3	Predator Unknown
2006	8	5	5.4	22	2	0.40	0	4	4	Weather Predator
2007	11	9	4.7	42	10	1.1	0	6	6	Predator
2008	11	10	4	28	8	0.8	1	6	7	Predator

Hardey *et al.* (2009) suggest that predation risk increases as young increase in size. If a predator has taken large young, evidence may include bitten off feather quills and trails of down feathers. They also conclude that there may be no signs to indicate small young are taken. In their study in Wales, Whitfield & Fielding (2009) suggested that partially eaten remains or 'chewed' feathers of the incubating female and/or nestlings were assumed to be evidence of predation by a mammal (Figure 2). Whitfield & Fielding had also asked observers to record corroborative evidence of the predator involved such as faeces, hair, feathers or distinctive scent. In the Langholm study, Dumfries & Galloway (Baines & Richardson 2013), a number of criteria were applied to assign causes of failure. In the Skye study, the only evidence found by the author was bitten and chewed feathers (Figure 1), or dead young or adults. In the majority of failures, and despite intensive searches in the vicinity of nests, there was no evidence of predation, which led to the decision to install digital nest-site cameras.

2009–12

The data shown in Table 2 from 2009 to 2012 were drawn exclusively from the North Skye study area. Camera evidence was available for several nests each year, and this was supported by other evidence such as chewed feathers and post mortem results. Over the four-year study, cameras were installed at 61% of nests. During the four year period the overall nest failure rate was 57% and based largely, but not exclusively, on camera evidence, 65% of failures could be attributed to foxes.

A total of eight camera activations resulted from fox intrusions, two when the young were less than two weeks old, and six when the young were more than two weeks old. After 2009, cameras were installed only on nests with young as this was considered to be the most vulnerable stage. However, a female incubating eggs was killed by a fox in 2010, confirming that nests with eggs,

Table 2. Summary of Hen Harrier breeding success, North Skye study area, 2009–12.

Year	Active territories	Nests	Mean clutch size	Total young hatched	Total young fledged	Mean fledged per nest	Failed with eggs	Failed with young	Total nests failed	Cause of failure
2009	7	6	5.6	16	9	1.5	2	2	4	Fox 2 Unknown 2
2010	12	10	5.4	36	10	1.0	1	6	7	Fox 6 Unknown 1
2011	12	9	5.25	25	15	1.6	0	3*	3	Fox 1 Unknown 2
2012	5	5	5.00	19	8	1.6	1	2	3	Fox 2 Unknown 1

**though 'RB3' was predated by a fox and two young killed, a single young fledged, so the site is regarded as successful.*

as well as brooding adults, can be vulnerable to foxes. In 2011, a nest was deemed to be 'successful' as a single young fledged despite its two siblings being killed by a fox on camera. Of the eight recorded predations on camera, only four (50%), had other evidence to indicate that a fox event had taken place. There was no evidence during the study of nests being visited by any other mammalian or avian predators. In 2012, a single nest failed late in incubation and though predation by a corvid could have been a factor, this could not be proved. Hooded Crows *Corvus cornix* were frequent nesting neighbours. Figure 3 provides examples of the camera evidence.

Plate 3. Intrusion of Hen Harrier nest by Red Fox, RBT site, Skye, 23 July 2010. (a) The initial intrusion at 02:24, then (b–c) fox returning at 21:28 to uplift the final dead youngster, which it had concealed. © *R. McMillan*

Predation of incubating adults

In 2010, an empty nest was located on 16 May with an adult female dead beside it (Plates 4 & 5). As this female was in moult, it was thought that it had been incubating a clutch of eggs and that these were subsequently removed by the fox.

Plates 4–5. Dead female Hen Harrier at the nest, Skye, May 2010. © *R. McMillan* **Inset.** Same dead female Hen Harrier as Plate 4 (Skye, May 2010) at the time of the post-mortem, with a fox skull and canines superimposed on the puncture marks. © *A.M. Wood*

The carcass was examined by A.M. Wood, an avian specialist at the Animal Health and Veterinary Laboratories Agency, Lasswade, Midlothian. The pattern of injuries found, with fairly symmetrical distribution of puncture wounds on both sides just behind the wings/axillae, together with the often paired puncture wounds in the skin and underlying muscles, suggested the bird had been killed by a fox. In the case of this territory, the male was then successful in attracting another female, which laid four eggs in a new nest some 200 m further west. Although four young subsequently hatched, the nest was predated by a fox on camera (see Plate 3).

On 2 June 2011, a nest containing six small young was found and a camera was installed (RB4 in Table 3). On 10 June, the nest was found to have been predated and the female was dead beside the nest. All the small young had been removed. Again the carcass was examined by Mr. Wood. The appearance was consistent with fox predation though maggot activity had enlarged some of the wounds. The bites on the neck indicated an experienced animal rather than a cub.

In each case, the dead female was left beside the nest. Because the carcasses were discovered and removed soon after the event, it is possible that a fox would have returned to uplift a carcass as food.

Table 3. Evidence of Hen Harrier breeding success from nest site cameras, Skye, 2009–12.

Year	Nest code	Date camera installed	Result	Remarks
2009	CH1	29 May on 6 eggs	Failed on eggs	Female deserted 6 June (lack of provisioning)
	RB1	29 May on 5 eggs	Fledged 4 young	
	RB2	4 June on 3 yg & 2 eggs	Fledged 5 young	
	GR1	4 June on 5 eggs	Fox predation 4 June @ 23:15	All 5 young killed
2010	RBL	14 June on 5 young	Fox predation 28 June @ 21:31	All 3 remaining young killed
	RBU	14 June on 3 yg & 3eggs	Fox predation 1 July @ 19:30	All 3 young killed, cubs brought to nest
	FB	18 June on 6 young	Fox predation (other information)	Camera malfunction, but all young killed
	CH1	18 June on 4 young	Fledged 3 young	
	GR1	25 June on 4 young	Fledged 4 young	
	RBT	12 July on 3 yg & 1 egg	Fox predation 23 July @ 02:20	All 4 young killed
2011	RB4	2 June on 6 young	Fox predation 4/5 June	Incubating ♀ & 6 young killed (infra-red failure)
	RB1	10 June on 4 young	Fledged 4 young	
	CH1	10 June on 4 young	Fledged 3 young	
	UIG	14 June on 4 young	Fledged 3 young	
	RB3	29 June on 3 young	Fox predation 13 July @ 02:00	Killed 2 young, but 1 on wing & fledged
2012	RB3	17.6 on 5 young	Fledged 3 young	Probably natural brood depletion
	RB5	12.6 on 5 young	Fox predation 2.7 @23:30	All 4 young killed
	CH1	12.6 on 5 young	Fledged 5 young	
	CH2	12.6 on 4 young	Fox predation 22.6 @ 01:00	2 young killed & ♀ defended nest but fox returned 10 days later & killed remaining 2 young

Discussion

Nest sites with cameras were visited more regularly than other sites. There is a view that foxes may have been attracted to these nests by human scent and trampling of vegetation. The introduction of larger batteries reduced the frequency of visits from every 5 or 6 days to every 7 or 8 days. As far as is practicable, walk-in approaches to sites were varied. Cameras were used at 19 nest sites during the study and 52% of these nests were successful. Prior to the camera study, between 2005 and 2008, of 31 nests which hatched young, only 14 nests were successful (45%). There was therefore no evidence to suggest that the installation of cameras increased the failure rate or predation risk.

In Galloway, Watson (1977) provided some evidence of fox predation. He also discussed nest failures, but attributed this to crows rather than foxes and suggested that successful nesting had occurred in areas where foxes are plentiful. In later years in Watson's study area, fox predation became an increasingly important factor and may well have been implicated to some extent in the extinction of forest-breeding Hen Harriers in Galloway by the mid-1990s (C.J. Rollie pers. comm.).

Simmons (2000) suggests that ground-nesting harrier species are susceptible to ground predators, with between 9% and 52% of all nests in a sample drawn from seven harrier species, destroyed by predators. He quotes a figure of 18% in a sample of 480 Hen Harrier nests from Picozzi (1984) in a study in Orkney, where there are no foxes, although there are ground-nesting crows on the moorlands.

Green & Etheridge (1999) examined Hen Harrier breeding success in relation to grouse moors and the Red Fox, but their data found no clear evidence for a beneficial effect of the control of foxes and other predators by moorland gamekeepers, on Hen Harrier nest success. Redpath & Thirgood (1997) provide some background to the long established study at Langholm. When fox and crow control ceased on the grouse moor in 2000, it was suggested that higher numbers of generalist predators impacted on other ground nesting birds including the hen harrier. (Baines *et al*. 2008). A later paper (Baines & Richardson 2013) provided a breakdown of nest failure rates and causal factors in the times when Langholm Moor was keepered and 'unkeepered', attributing predation by foxes as the main cause of harrier breeding failure.

In Hen Harrier population studies in Wales, Whitfield & Fielding (2009) found that of 86 failed breeding attempts where a cause of failure was attributed, 20 nest losses were due to fox. O'Donoghue (2012) found that predation was a significant issue in Ireland, with 19% of nests lost to predators including foxes. Fielding *et al*. (2011) referred to previous work (Watson) which suggested that variation in the aggressiveness with which harriers defend their nests may affect the susceptibility of eggs and chicks to predation, as may the attentiveness of the parent birds, which may be influenced by the availability of prey (Amar & Burthe 2001). In the Skye study, there was no evidence that either of these factors makes any difference. The aggressiveness and

Plate xx. Caption. © *Laurie Campbell*

attentiveness of adult females may be a factor during daylight hours, but in the camera study, six of the eight nest site intrusions by foxes occurred during the hours of darkness. In 2012, a female harrier aggressively defended her nest to a fox intrusion during darkness but lost two chicks initially, and the remaining two in the brood, two weeks later. Although not all harriers flee when a fox intrusion occurs, evidence from this study suggests they offer little resistance to a persistent fox attack and may well be at risk themselves. Though all the young may not be taken initially, they will invariably be killed eventually. Of the two intrusions which occurred during daylight hours, in one instance two live young were left in the nest until the fox returned with cubs two hours later to remove them. The camera images failed to show any resistance by the adult birds. In 2005, a webcam at a nest site at Clyde Muirshiel Park recorded the systematic reduction of a brood of five young Hen Harriers to a single chick, which successfully repelled the fox (C.J. Rollie pers. comm.). No chick on Skye has been recorded successfully repelling a fox.

The long-established practice of claiming birds have fledged at the point of ringing or when the young are fully feathered may be unreliable, but remains part of guidance (Hardey *et al.* 2009). In 50% of the camera activations in this study, there was no other evidence to suggest that there had been a fox intrusion at the nest, in other words there had been a 'clean lift' by foxes at the nest. There is a risk that failures could be attributed to other causes. It might therefore be useful to include 'nest failure rates' as well as fledging rates, as indicators of the health of Hen Harrier breeding populations. In areas not managed for Red Grouse, high failure rates at the chick stage may well indicate a problem of fox predation.

Nest site cameras were deployed as part of the Langholm project between 2008 and 2013 on a total of 11 nests, two of which failed, but with no evidence of fox intrusions. However, there had been intensive control of foxes during this period (A. McCluskie pers. comm.). Whilst it might be argued that foxes will be intensively controlled on all sporting estates, recent analysis of data from Atholl Estates in Perthshire (McMillan 2011, pers. obs.) shows that 'predator' control on some grouse moors can be highly variable and directly relates to the efficiency/commitment of individual gamekeepers. The possibility that Hen Harrier nests will be predated by foxes on some grouse moors cannot be excluded, and in the context of Langholm, it appears that in 1999, when grouse moor management was still in place, there was a sudden occurrence of four nest failures attributed to foxes, in addition to which, two adults were killed on nests (Baines & Richardson 2013). There had been no fox events in the preceding six years of the study. In the subsequent 'unkeepered' phase of the study 2000–07 there was an average of a single identified fox event each year. At Langholm, 1993–2007, there were a total of 130 breeding attempts from which there were 41 nest failures and 56% of these occurred when the birds were on eggs. In the Skye study, 2000–12, there were 88 breeding attempts with a total of 47 failures, 28% of which were on eggs. The contrast between the two datasets is interesting. The general view amongst raptor workers is that most fox intrusions occur when broods are at the later stage of development and that is supported by results from the Skye study. This is not to say that fox predation did not occur at Langholm, but human disturbance, deliberate or otherwise, may have been a factor given the disproportionate number of failures on eggs.

Whilst Fielding *et al.* (2011) acknowledge that foxes can be important predators they were not included as a predictor in the harrier distribution model. They also concluded that fox impact seems to be largely on harrier productivity rather than distribution, supported by observations by P. Haworth in Kintyre, where breeding harriers and foxes appeared to be abundant. However, these observations are at odds with studies of two areas of Mid-Argyll and north Kintyre, where breeding birds have disappeared and this has been attributed to a large proportion of failures due to predation, possibly by foxes (ap Rheinallt *et al.* 2007). J. Halliday (pers. comm. 2013) has updated these data showing that four territories in Kintyre occupied in 1997–2008, were abandoned and this he attributed to a high incidence of failure due to predation, with foxes the most likely predator. Also

in Argyll at the Moine Mhor NNR, J. Halliday reported that up to three pairs had bred between 1989 and 1996 when the territories were abandoned. Although birds returned in 2010 and 2011, there were further failures and J. Halliday suspected that high rates of predation, probably by foxes, and lack of recruitment to the population also explained the demise of this population. In a study in Cowal, Argyll, from a population of eight pairs in 2003, only a single pair bred successfully in 2013 and fox predation is considered to be a factor in the population decline (A. French pers. comm.). During the course of this study, breeding pairs disappeared from south Skye with the exception of 2011, when a pair returned after a 10-year gap, but failed.

Madders (2010) noted that the extent of first rotation forestry was in decline in the west of Scotland and predicted that the loss of this habitat would lead to a reduction in numbers of harriers breeding. New *et al.* (2011) modelled the population dynamics at Langholm. In afforested areas, as the canopy closes and small mammals reduce in numbers, New *et al.* suggest that in the long term the population size could not be maintained as there would not be enough young harriers to replace the older birds lost to the population. However, in the context of the Skye study, whilst there have been some population fluctuations, clutch and initial brood size has remained high, suggesting that lack of food has not been a factor. The difficulty has been brood survival and nest failures as a result of fox predation. In the context of the 'New' model, with fewer young birds fledging, or occasional breeding adults predated by foxes, the problem of recruitment to the breeding population would be exacerbated. Evidence from Skye, and a number of other areas, suggests that successive failures as a result of predation may contribute to the abandonment of territories, making populations less viable, and in some regions directly impacting on distribution.

Digital nest site cameras have proved to be an extremely useful research tool and the images, along with other material found at nest sites, provides compelling evidence that fox predation of Hen Harrier nests on Skye is considerably higher than that apparently recorded in any other area of the UK or Ireland. The technology would seem critical for any future research into establishing causes of nest failure or brood depletion.

Hayhow *et al.* (2013) reported that the breeding population of Hen Harriers in the UK and Isle of Man declined between 2004 and 2010. They concluded that a 20% decrease in Scotland may be related to habitat change and illegal persecution. It appears that further declines occurred in 2012 which has prompted SNH to commission additional work on the Hen Harrier Conservation Framework (SNH 2013). In the Skye study, only three nests were found in 2013, the lowest number recorded since the study commenced.

Problems of human persecution remain a priority for the conservation of this species. However, it cannot be the exclusive focus when there are clearly other problems in forests and moorlands not managed for other sporting interests. The challenges facing Hen Harriers are complex, but when high nest failure rates occur there is a need for a detailed interpretation of causal factors.

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