Research Report No. 1209

Heads up for Harriers - Image analysis 2015-2019

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To be transparent about our work and publications on protected species we have redacted information in this report pertaining to hen harrier nest locations and the identification of estates that have participated in the Heads Up for Harriers project – this latter is at the request of the estates.

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RESEARCH REPORT

Summary

Heads up for Harriers - Image analysis 2015-2019

Research Report No. 1209
Project No: 115542
Contractor: Brian Etheridge
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hen harriers; moorland estates; nest cameras; breeding success; land use; nest failures; prey

Background

Heads Up for Harriers is a partnership project started in 2015 which seeks to better understand the reasons for hen harrier *Circus cyaneus* nest failure and to work with land managers to (where possible) rectify these. The project is one of the key outputs of the Partnership for Action Against Wildlife Crime Scotland (PAW Scotland) Hen Harrier Action Plan.

Project members are NatureScot (Chair and project management), Scottish Government, Scottish Land and Estates (SLE), RSPB Scotland, National Wildlife Crime Unit, Forestry Commission Scotland (now Scottish Forestry) and Forest Enterprise Scotland (now Forestry and Land Scotland).

The project itself comprises two main elements: monitoring of hen harrier nests using nest cameras; and increasing public awareness of harriers through the use of media and the project web pages, hosted on the Scottish Government website: https://www2.gov.scot/Topics/Environment/Wildlife-Habitats/paw-scotland/what-you-can-do/hen-harriers

This report is concerned with the analysis of images obtained from nest cameras and identification of any trends that may influence survival to fledging.

Main findings

- Over a 5-year period, 2015-19, 26 estates participated in the *Heads up for Harriers* scheme for a total of 84 estate/years.
- 52 hen harrier nests were found and 35 were successful in fledging 120 young.
- Trail cameras were installed at 37 nests and over two million images recorded.
- Langholm Demonstration Moor had the highest number of nests, highest nesting success (79%) and highest number of fledged young of all participating estates.

- Estates not managed for grouse shooting had a higher number of nests, higher nesting success and higher number of fledged young than those managed for walk-up or driven grouse shooting.
- Amongst 38 pairs, 26% of females were one-year old and a further 26% were either two or three-years old. The rest were four years or older. In males, 13% were one-year old, the remainder were in adult grey/white plumage.
- Pairs where the male was in adult plumage had high breeding success (91%) irrespective of the female age.
- One-year old males were found breeding on five occasions and only with one-year old females. They had a 40% breeding success.
- Estates with no game-bird shooting had the lowest number of one-year old first-time breeders (5%) compared with 50% on estates with some form of game-bird shooting.
- Of the 17 nesting failures, the cause or probable cause of 13 could be determined. None was due to direct human persecution.
- Prey and provisioning were examined at a sample of six nests over 39 full days. Nearly 500 prey items were delivered. Of those identified, 89% were birds and 10% were mammals. Meadow pipits were by far the most abundant prey representing 77% of birds. Young red grouse occurred 17 times (5.6% of birds). Provisioning increased with chick age and brood size, reaching a peak of 20-28 items a day when young were 2-3 weeks old before declining as they approached fledging at 4-5 weeks.

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Acknowledgements

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1. INTRODUCTION

Hen harriers in UK breed on heather moors and feed on moorland species such as field voles *Micotus agrestis,* meadow pipits *Anthus pretensis* and red grouse *Lagopus lagopus*. The predation of the latter brings harriers into conflict with grouse-moor owners and their gamekeepers who wish to conserve grouse stocks for shooting. The outcome is the widespread killing of adult birds and the destruction of their nests (Etheridge *et al*., 1997). Hen harriers are considered by both conservation organisations and Government bodies as one of the most widely persecuted bird of prey species in the UK (Avery, 2015; Fielding *et al.,* 2011). This is despite having some of the highest levels of protection under the Wildlife & Countryside Act 1981.

The intensity of grouse-moor management and levels of persecution has risen sharply in recent years to such an extent in England and Scotland that harriers are currently absent as a breeding species on almost all driven grouse-moors and has become scarce elsewhere (Avery, 2015). There have been many studies over the past 25 years which highlight the problem and various initiatives have been put forward to tackle the harrier/grouse-moor dispute (Thompson *et al.,* 2009). However, attitudes of game managers and the pro-shooting lobby remain entrenched and hen harriers and other birds of prey continue to be the losers. Frustrated by inaction, conservationist have been petitioning Government calling for either the licensing of grouse shooting and gamekeepers (HM Government e-petition website 46473) or an outright ban of driven grouse shooting because grouse estates appear incapable of operating within the law (HM Government e-petition website 65627). Moreover, this criminal activity is compounded by environmental issues relating to heather burning and the release of carbon, moorland drainage and the link to flooding and the continued use of toxic lead shot (Avery, 2015).

The creation of the *Heads up for Harriers* project has provided moorland owners and sporting estates in Scotland the opportunity to demonstrate that they reject illegal persecution and are willing to work with Government to safeguard breeding hen harriers on their land.

2. METHODS

2.1 Estate involvement

Since 2015 SLE member estates were approached by Scottish Land and Estates to participate in the project. In addition, since 2017, some estates in Highland were approached by Brian Etheridge (BE) along with Scott Smith (SS) in capacity as project field workers in order to boost the number of estates involved.

The search for breeding hen harriers on participating estates was carried out by either the two project field workers or on some of the estates with driven grouse-moors by their own gamekeepers. As soon as a nest was located a distant surveillance camera was installed. A nest camera was installed once the eggs had hatched. The cameras were removed after the young had fledged or the nest had failed.

2.2 Surveillance camera

A time-lapse trail camera, Day 6 Plotwatcher Pro, was installed at a distance (50-100m) from an active nest as soon as it was located. The camera was either fixed at ground level with a cable tie to a camouflaged painted 50x50mm wooden stake 30-40cm long driven into the ground or attached at 1.5m to a tree trunk with straps. These cameras do not have infrared night vision capability and were programmed to take one image every 10 seconds between dawn (03.00) and dusk (23.00).

The images taken were of low resolution and it meant a camera did not require frequent battery or SD card renewal and could be left in place without visits until after the young had fledged or the nest had failed. Their main purpose was to record human and large mammalian intruders at an early stage of the breeding cycle prior to the nest camera being installed.

2.3 Nest camera

Three models of compact motion-triggered trail cameras, Reconyx XS8UltraFire, Reconyx HC600 Hyperfire and Little Acorn 6310WMC were installed at active nests which contained chicks. In North Scotland Reconyx HC600 HyperFire cameras were used only in 2015 before being transferred for use in South & Central Scotland. From 2016 in North Scotland, Ltl Acorn 6310WMC Scouting Cameras were solely deployed. Cameras were not deployed earlier during clutch incubation to avoid unnecessary disturbance and the increased likelihood of desertion at the egg stage (Hardey *et al*., 2013).

The model of Acorn cameras used had camouflaged plastic case, a wide-angle lens and low-glow covert infrared night vision. They were fixed with a cable tie to a post similar to that in use for the surveillance cameras and positioned at ground level 50-60cm from the centre of the nest and partially concealed in the surrounding heather. Reconyx XS8 UltraFire and Reconyx HC600 are covert field surveillance infrared trail cameras offering 1080p HD video at 30 frames per second. They lack the wide-angle lens and were installed further back at one metre from the nest on a slightly raised post.

Occasionally nest cameras were programmed to shoot video but in order to increase battery and SD card life and thus reduce the number of visits to nests, they were mainly set-up to take one to three photographs when triggered by movement followed by a 10 second break before a further triggering was possible. This extended the working period of the camera to 7-10 days before they needed replacing with a fully charged one. It was found that changing the camera rather than the batteries and SD card separately greatly reduced the time at the nest and the period of disturbance.

2.4 Power source

All four types of cameras were powered by 1.5v AA batteries. The Plotwatcher required eight Duracell Plus Alkaline batteries and the Reconyx and Acorn twelve Energizer Ultimate Lithium. All images were recorded on 32GB SD cards (Integral, Kingston and SanDisk) and later transferred and stored on 2TB Western Digital My Passport Wireless Pro computer external hard drives. SD cards were provided upon request to the participating estates at the end of each season.

3. RESULTS AND DISCUSSION

3.1 Participating estates

The number of private estates participating in *Heads up for Harriers* increased annually from four in 2015 to 24 in 2019 despite two of the 2015 estates later withdrawing (Table 1).

Table 1. Heads up for Harriers participating estates 2015-19.

Estate	County/District	Period involved	Participating years
[redacted]	Moray	2015-2019	5
	South Ayrshire	2015	1
	Badenoch & Strathspey	2015-2016	2
	Ross-shire	2015-2019	5
	Aberdeenshire	2016-2019	4
	Aberdeenshire	2016-2019	4
	Lanark	2016-2019	4
	Ayrshire	2016-2019	4
	Aberdeenshire	2016-2019	4
	Angus	2016-2019	4
	Angus	2016-2019	4
	Aberdeenshire	2016-2019	4
	Angus	2016-2019	4
Langholm	Dumfries	2016-2019	4
[redacted]	Angus	2016-2019	4
	Badenoch & Strathspey	2016-2019	4
	Angus	2017-2019	3
	Ross-shire	2017-2019	3
	Ross-shire	2017-2019	3
	Lanark	2016-2019	3
	Sutherland	2018-2019	2
	Inverness-shire	2018-2019	2
	Nairnshire	2018-2019	2
	Moray	2018-2019	2
	Angus	2018-2019	2
	Inverness-shire	2019	1

3.2 Hen harrier nests located and breeding success

The total number of nests located across all participating estates varied between five in 2015 and a maximum of 17 in 2018. A total of 52 nests were recorded over the 5-year period (Table 2). Of the 52 monitored nests, 35 (67.3%) were successful in fledging at least one young. One hundred and twenty young were produced giving a mean brood size of 3.4 young per successful nest and 2.3 young per monitored nest. These data are similar or slightly higher than that collected in a large sample of nests monitored on unmanaged moorland in Scotland in 1988-95 (Etheridge *et al.,* 1997).

Table 2. Number of hen harrier nests located and young fledged on Heads up for Harriers estates.

Year	Number of nests monitored	Number of nests rearing young (%)	Number of young fledged
2015	5	3 (60%)	12
2016	6	6 (100%)	15
2017	12	9 (75%)	37
2018	17	9 (53%)	29
2019	12	8 (67%)	27
TOTAL	52	35 (67%)	120

3.3 Trail cameras deployed

Table 3 shows the deployment of cameras at active nests. On some estates a nest failed before a surveillance camera could be installed or failed after it was installed but before a nest camera could be deployed. In a few cases where the nest was found at the chick stage, the surveillance camera was omitted and only a nest camera was deployed.

Nest cameras were deployed at 37 nests and 2,028,704 images were recorded over a total of 822 days, an average of 54,830 images and 22.2 days of observations per nest.

Images from the surveillance camera were only examined in the event of a nest failure to help determine the cause. The lack of infrared technology meant that events leading to failure that occurred during the hours of darkness were not recorded.

Table 3. Observation days and nest camera images captured per year, estate and site at hen harrier nests, 2015-2019.

Year	Estate	Site name	Nest camera observation days	Number of camera images
2015	[redacted]	[redacted]	no camera	-
2015	[redacted]	[redacted]	no camera	-
2015	[redacted]	[redacted]	no camera	-
2015	[redacted]	[redacted]	23	20,002
2015	[redacted]	historic site	18	38,699
2016	[redacted]	[redacted]	10	41,596
2016	Langholm	[redacted]	34	56,661
2016	Langholm	[redacted]	28	44,120
2016	Langholm	[redacted]	34	65,956
2016	[redacted]	historic site	16	52,319
2016	[redacted]	[redacted]	no camera	-
2017	[redacted]	[redacted]	25	813
2017	[redacted]	[redacted]	10	24,356
2017	[redacted]	[redacted]	9	25,209
2017	[redacted]	[redacted]	18	61,708
2017	[redacted]	[redacted]	37	73,667
2017	[redacted]	[redacted]	54	123,751
2017	[redacted]	[redacted]	30	91,493
2017	[redacted]	[redacted]	27	60,460
2017	[redacted]	[redacted]	46	66,993
2017	[redacted]	[redacted]	no camera	-
2017	[redacted]	[redacted]	3	31,219
2017	[redacted]	[redacted]	22	30,216
2018	[redacted]	[redacted]	no camera	-
2018	[redacted]	[redacted]	no camera	-
2018	[redacted]	[redacted]	9	20,383
2018	[redacted]	[redacted]	17	49,043
2018	[redacted]	[redacted]	17	23,751
2018	Langholm	[redacted]	10	40,264
2018	Langholm	Nest 2	no camera	-
2018	Langholm	[redacted]	42	145,245
2018	Langholm	[redacted]	no camera	-
2018	[redacted]	[redacted]	20	46,745
2018	[redacted]	rough track	14	20,800
2018	[redacted]	[redacted]	34	69,573
2018	[redacted]	[redacted]	14	25,390
2018	[redacted]	historic site	11	12,144
2018	[redacted]	[redacted]	no camera	-
2018	[redacted]	[redacted]	no camera	-
2018	[redacted]	[redacted]	10	28,747
2019	[redacted]	[redacted]	no camera	-
2019	[redacted]	[redacted]	no camera	-
2019	[redacted]	[redacted]	no camera	-
2019	[redacted]	[redacted]	10	144,509
2019	Langholm	[redacted]	36	211,138
2019	Langholm	[redacted]	16	119,946
2019	Langholm	[redacted]	1	2,407

2019	[redacted]	33	22,988
2019		50	70,401
2019		30	32,341
2019		4	33,651
2019		no camera	-

3.4 Moorland land use and nesting hen harriers

All nests occurred on open moorland dominated by heather *Calluna vulgaris*. The moors were managed in a variety of ways (Table 4 and summarised in Table 5):

- for conservation and native woodland regeneration
- for limited summer grazing by sheep/cattle but no red grouse shooting,
- for less intensive walked up shooting
- for driven Red Grouse shooting
- as a raptor & Red Grouse demonstration moor

[redacted] is a company that owns several sporting estates in the Highlands. Their estates are managed for conservation with no burning and little or no predator control. Two of their Badenoch & Strathspey estates, [redacted], are adjacent. They have been involved with the project for four years and ten hen harrier nests have been found, six were successful (60%) and 15 young fledged.

On five estates, the moors had no grouse shooting, with three of them receiving summer grazing by sheep *Ovis aries* and/or cattle *Bos taurus*. In the combined 13 estate years, 16 nests were found and monitored, 12 were successful (75%) with 40 young fledged.

The moors on five estates were managed less intensively and any grouse shooting was by "walk up" together with deer stalking. Most of these estates employed low-ground gamekeepers. Over a combined 14 estate years, seven nests were found and monitored and four were successful (57%) with 16 young fledging.

Fourteen (56%) of the 25 estates involved in the scheme had driven grouse-moors employing full time keepers. Despite their involvement for 46 estate years only four nests were found. Just one was successful (25%) and produced four young.

Langholm Moor Demonstration Project became a *Heads up for Harriers* partner in 2016. Management at Langholm embraced traditional grouse-moor techniques such as heather cutting, bracken removal and the full legal control of predators. In four years, 14 nests were monitored and 11 were successful (79%) with 45 young fledged.

Breeding harriers occurred at least once on nine of the eleven estates with limited or no grouse shooting. By comparison, breeding harriers occurred only on four occasions on the fourteen estates with driven grouse-moors. The combination of estate involvement in the scheme and the number of years they were involved gave a combined total of 84 estate years.

There was a negative relationship between the occurrence and intensity of grouse shooting on an estate and the number of hen harrier nests located. This was despite the number of estates with driven grouse-moors having the largest land area (Table 4) and potentially the greater chance of having harrier pairs. Langholm demonstration moor provided an indication of the potential hen harrier population on a grouse-moor when measures are put in place to conserve them.

Table 4. Participating Heads up for Harrier estates, moorland management, hen harrier nests found and fledging success, 2015-19.

Estate	Ha.	Moorland management	Years	Nests found	Successful nests	Fledged young
[redacted]	27,195	conservation, deer control only	4	10	6	15
	2,678	no grouse shooting	5	7	4	14
	2,020	no grouse shooting	3	1	1	5
	4,639	no grouse shooting	3	4	4	13
	4,750	no grouse shooting	3	0	0	0
	4,301	no grouse shooting	2	4	3	8
	8,309	limited shooting, walk-up	5	3	2	9
	11,824	limited shooting, walk-up	4	0	0	0
	6,507	limited shooting, walk-up	2	2	1	3
	3,225	limited shooting, walk-up	2	1	1	4
	5,815	limited shooting, walk-up	1	1	0	0
	2,452	driven grouse-shooting	4	0	0	0
	6,141	driven grouse-shooting	4	0	0	0
	13,355	driven grouse-shooting	4	0	0	0
	-	driven grouse-shooting	4	0	0	0
	4,050	driven grouse-shooting	4	0	0	0
	6,909	driven grouse-shooting	4	0	0	0
	3,964	driven grouse-shooting	4	0	0	0
	17,669	driven grouse-shooting	4	0	0	0
	7,893	driven grouse-shooting	4	0	0	0
	5,573	driven grouse-shooting	3	3***	0	0
	5,273	driven grouse-shooting	2	0	0	0
	5,599	driven grouse-shooting	2	1	1	4
	3,237	driven grouse-shooting	2	0	0	0
	3,816	driven grouse-shooting	1	0	0	0
Langholm Moor	7,600	Demonstration grouse-moor	4	14	11	45
Total	**174,794**		**84**	**51**	**34**	**120**

* [redacted]
** I am unable to identify Dumfries estate by this name.
*** The three clutches were incubated well beyond normal time suggesting parent infertility as indicated by egg analysis by Predatory Bird Monitoring Scheme and SASA DNA analysis.

Table 5. Heads up for Harriers estate moorland management, hen harrier nests located, nesting success and young fledged, 2015-19.

Moorland management	Number of estates	Combined years involved	Total nests located	Mean number of nests per year	Total successful	Total fledged young
Conservation, deer control only	1	4	10	2.5	6	15
No grouse shooting, some grazing	5	16	16	1.23	12	40
Limited grouse-shooting, walk-up	5	14	7	0.5	4	16
Driven grouse-shooting	14	46	4	0.09	1	4
Demonstration grouse moor	1	4	14	3.5	11	45

3.5 Causes of nest failure

Of the 52 nests monitored, one third (33%) failed completely, nine during the incubation phase and eight when the nest contained young (Table 6). The cause of nest failure could be determined in eight cases and the most probable cause determined in a further five.

Table 6. Hen harrier nest failures, Heads up for Harriers estates, 2015-19.

Cause	Number of failures
Egg stage	
Clutch infertile	3
Deserted after camera installed	1
Failed after wild fire	1
Probable red fox predation	1
Clutch missing, no evidence	3
Chick stage	
Confirmed red fox predation	1
Confirmed long-eared owl predation	1
Confirmed brood starvation	1
Probable red fox predation	1
Probable mammal predation	3
Chicks missing, no evidence	1

Red fox *Vulpes vulpes* predation was confirmed at one nest, was likely at a further two and may have occurred three more. Moreover, a fox led to the predation of small young by a long-eared owl *Asio otus* by disturbing the brooding female from the nest at night leaving the young exposed to attack. These events occurred during the hours of darkness. However, a fox was driven off by a fledged brood of five following an attack during late morning (Figures 8, 9 & 10). This attack could have been fatal to the brood if they had been any younger. One nest failed when the breeding female, an inexperienced one-year old and probably involved with a bigamous male, failed to feed her two young adequately causing them to starve to death (see Appendix, page 19).

Three clutches, all from the same driven grouse-moor estate and possibly involving the same pair, proved to be infertile. One clutch was deserted in 2019 after an excessively prolonged period of incubation which coincided with an uncontrolled wild fire in the vicinity. The fire and smoke may have kept the female off the nest and resulted in the eggs chilling. Another clutch was deserted after the installation of a nest camera at an early stage in the incubation. This happened at the beginning of the project in 2015 involving the first nest found. The pair laid a replacement clutch elsewhere on the estate and raised young (reported by local raptor study group). Following this event (with one exception in 2017), cameras were only installed at a nest when they contained young where the risk of desertion was considered minimal.

There were four cases of unexplained failure. Three resulted in the complete loss of a clutch and one the loss of small young before a nest camera could be installed. One nest not listed in Table 6 underwent an unexplained partial clutch reduction from five to three eggs between visits. The images from the surveillance camera revealed the female harrier being flushed off the nest in the evening by large herd of red deer *Cervus elephus* descending the hillside where the nest was situated to feed on grassland in the valley floor. The disturbance lasted for over an hour and at one stage a large gull *Larus sp.* is recorded by the surveillance camera flying over the nest slope where the absence of the female harrier may have given the gull the opportunity to raid the nest.

Details of some of the individual nest failures are provided in the Annex 1.

3.6 Impact of weather

Warm dry weather during the spring and early summer months can have major benefits for a wide range of moorland species particularly the young of meadow pipits on which harriers are so dependant. The negative side to this is that it can encourage more muirburn with the increased risk of wildfires, as happened in the spring of 2018 and 2019. Prolonged wet weather reduces the productivity and abundance of prey species and curtails the opportunity and efficiency of hunting. In the long dry spring and summer of 2018, the nests of more breeding pairs of hen harriers were detected and the number of young produced was much higher than in any of the other project years (Tables 2 & 3) despite a high failure rate at Langholm.

Bad weather was known to negatively affect one nest. In June 2016, a prolonged 3-day period of cold winds and rain from the north east affected Moray and Aberdeenshire districts. At the time one nest in Moray with five young was under nest camera surveillance. The female was forced to start hunting to supplement the males reduced foraging success. This resulted in reduced brooding and an increased risk of chilling of the young. Over the three days of bad weather the two youngest in the brood weakened and died.

3.7 Altitude and aspect

This was examined at nests in Highland and Moray. The altitude of nests was recorded by either using a Garmin GPS device or from plotting on a 1:25000 OS map. Altitude varied between 140m on the [redacted] estate, close to the east Sutherland coast to 520m on [redacted] in the Cairngorms. The majority of nests (62%) were in the range 250-400m. Altitude had an impact on nesting success varying from 63% for nests below 300m, 78% in the range 300-400m and 50% above 400m.

The aspect of nests showed a strong preference (47%) towards the west (6 nests) or south-west (10 nests). This preference increased with altitude. Below 300m, two of eight nests (25%) were in a westerly direction, between 300 and 400m, 10 of 18 nests (56%) were in this direction, whilst above 400m, six out of eight nests (75%) faced west.

The prevailing wind direction in Highland in the summer months is from the southwest and from this direction most of the wet weather comes. Higher altitudes receive stronger winds, greater rainfall and lower temperatures. Thus, the combination of aspect and altitude and the tendency for higher nests to face in a westerly direction, could be the reason for their reduced breeding success. Conversely, the lower altitude nests exposed to more benign weather enjoyed higher breeding success.

3.8 Age of parent birds

Both sexes can reach sexual maturity when one year old and are capable of breeding even though they will be still in juvenile plumage (Balfour, 1970). Juvenile male and juvenile female hen harriers have a plumage similar to an adult female. The three categories are commonly called 'ring-tails'. This plumage is retained until a full moult occurs during the summer and early autumn of their second calendar year i.e. when the birds are one-year old and entering their second. Following this moult, males acquire a distinctive grey and white plumage with black outer primaries but with varying number of retained juvenile feathers on the mantle and back (Figure 5), so called 'saddle-backs'. The full adult male plumage is finally acquired after the next moult when they are two years old and entering their third. Thus, the ageing of one-year old breeding males by plumage is straight forward but a good view of the upperparts is needed to age two-year old males.

For females where the plumage of one-year old and older birds is similar, ageing can be carried out using iris colour which in one-year old birds is dark brown (Figure 2), in two and three year old birds honey-brown to amber with a decreasing amount of brown flecks (Figure 3) and in adults, four years and older, the iris is unmarked pale yellow (Figures 4 & 6) (after Balfour, 1970; Hamerstrom, 1986).

Though eye colour can be difficult to see in the field, it is easily obtained from nest camera images. Using these characteristics, the age of the breeding pair was determined at 38 nests (Table 7). From this sample, 26% of females were breeding when one year old and the same proportion (26%) bred when two or three years old. For males the proportion breeding at one year old was half that of one-year old females at 13%. Two-year males were harder to identify from nest images, one was identified but the true proportion breeding at this age is unknown. Thus, they are all classed as adult males in tables 7 and Table 8 with a minimum age of two-years.

The criteria for one-year old females was confirmed in two cases - they had both been ringed the year previous as nestlings (Annex 3).

Table 7. Age of breeding hen harrier pairs based on iris colour of females from nest camera images and plumage of attending males.

Year	Nest sample	One-year old females (dark brown iris)	Two & three-year old females (amber/honey-brown iris with brown flecks)	Adult females min. four-years old (pale unmarked yellow iris)	One-year old males (brown plumage)	Adult male min. two-years old (grey plumage)
2015	2			2		2
2016	6	1	3	2		6
2017	10	3	2	5	1	9
2018	12	5	3	4	4	8
2019	8	1	2	5		8
Total	38	10 (26%)	10 (26%)	18 (47%)	5 (13%)	33 (87%)

3.9 Impact of age on breeding success

There was a noticeable effect of the age of a breeding pair on their nesting success and productivity (Table 8). Pairs comprised of a female aged two or three year or older and a male in grey-plumage reared larger broods than other pair combinations. Pairs with a one-year old female and an older grey-plumaged male also had good breeding success though not as high as older pairs. They also produced fewer young. Pairs consisting of both one-year old females and males bred least successfully and produced the smallest average broods. There were no recorded pair combinations consisting of one-year old males and an older female. This suggests that older females avoided breeding with males in a brown immature plumage and only selected the older grey plumaged males. Although the sample of breeding one-year old males is small, only two (40%) of the five nesting attempts in which they were involved were successful. The comparison figure for older grey males is 31 out of a sample of 33 (94%).

Table 8. Occurrence and breeding success of hen harrier pairs according to their age. Females were aged by iris colour and males by plumage.

Age of pair	Number breeding	Number successful (%)	Number of young fledged	Mean brood size fledged per breeding pair
One-year old female One-year old (brown) male	5	2	8	1.6
One-year old female Adult (grey) male	5	5	12	2.4
2 & 3-year old female One-year old (brown) male	0	–	–	–
2 & 3-year old female Adult (grey) male	10	10	38	3.8
Four + year old female One-year old (brown) male	0	-	–	–
Four + year old female Adult (grey) male	18	16	58	3.2

3.10 Age of breeding hen harriers in relationship to moorland management

Estates with heather moorland where there was no grouse or game-bird shooting had the lowest proportion of one-year old hen harriers (5%) amongst those pairs attempting to breed (Table 9). Langholm demonstration moor recorded no one-year old birds breeding. Estates with driven grouse-moors, less intensive walk-up shooting and conservation moorland differed strongly with around 50% of breeding birds in first-year plumage suggesting a higher annual turn-over in the harrier breeding population.

This was a surprising result for conservation moorland where the proportion of birds in adult plumage might be expected to be much higher where there is less active management. However, this result is for just one very large land holding which just before the start of the project had changed ownership leading to the cessation of driven grouse-shooting and the commencement of a policy of conservation and native woodland regeneration. There had been no breeding harriers on this estate for more than a decade prior to the start of the project (Dave Pierce *pers. com*). It seems likely that the change in the way land was managed and possibly the estates involvement in *Heads up for Harriers* led to the

establishment and growth of a breeding population of hen harriers during the study and initially this may have been by first time breeders consisting of some first-year birds.

All of the driven grouse-moor estates, three of the walked-up grouse estates and the conservation moorland estate had neighbouring estates with intensive driven grouse-moors. The impact of predator control by neighbouring grouse-shooting estates may have had an effect on *Heads up for Harriers* estates and the occurrence and age of any Hen harriers attempting to settle on them. This did not apply to any of the four non-shooting estates, none of which had grouse shooting neighbours. It is likely that the age ratio on the non-shooting estates were more representative of a natural hen harrier population.

Table 9. The age of breeding hen harriers in relationship with moorland management.

Age/Sex	Driven grouse-moor (n=1)	Low intensive walk-up shooting (n=5)	No grouse shooting (n=4)	Wildlands conservation moor	Langholm demonstration moor
One-year old female	1	3	1	4	0
Two & three-year old female	-	1	2	3	4
Four-years & older female	-	2	7	0	8
One-year old male	-	3	0	2	0
Two-years & older male	1	3	10	5	12
% of one-year old birds	50%	50%	5%	43%	0%

3.11 Nest camera images

Figure 1. Adult male delivering a large Red Grouse chick to a nest on [redacted], 28 June 2019. The brood size at this nest was just one.

Figure 2. One-year old female brooding four downy young, [redacted] estate, 19 June 2018. Note the dark brown iris.

Figure 3. Two or three-year old female feeding a brood of five young, Langholm demonstration moor, 5 July 2016.

Figure 4. Adult female brooding small young, [redacted] estate, 8 June 2017. Note the pale-yellow iris, indicating the bird's age is at least four years.

Figure 5. Male hen harrier brooding small young, [redacted] estate, 14 June 2017. This rare event lasted only a few minutes before the female returned. The mottled brown/grey feathers on the mantle, indicate that this is a two-year old bird born in 2015. In older males it is unmarked pale grey.

Figure 6. Bedraggled adult female, [redacted] estate, 16 June 2016. Despite the very wet conditions, the adult pair brought in 28 small prey items during a 14-hour period.

Figure 7. Adult female landing at same nest in Figure 6 with prey, 18 June 2016.

Figures 8, 9 & 10. Unsuccessful fox attack at a nest with five fledged young, Langholm Moor, 11.46 am, 16 July 2016.

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ANNEX 1. NEST FAILURES

2015. [redacted] estate

Female age unknown. Male adult (two+ years).
Nest in heather at 350m on gentle slope below steeper bank on west facing hillside.

9 June, 15.00 hours. Food pass seen. Nest contained two young (5 & 7 days old) and four eggs, at least two had watery contents. Plotwatcher installed at [redacted] 200m from nest at same altitude.

24 June, 11.20 hours. Nest contained two young and four eggs. Permission to install a nest camera was denied by NatureScot staff at the nearby Elgin office and the wind farm ecologist over their concerns about nest abandonment. This was lifted in the following year.

14 July, 10.20 hours. Nest visit. Young missing. Evidence of brood predation by fox. Bitten off primary feathers found 5m from nest. No adult birds seen. Single egg had a hole in side suggesting crow attention after the brood predation event. Plotwatcher removed.

Plotwatcher camera. 311,040 images from 9 June to 14 July.
At the requests of the wind farm ecologist the camera had been installed at a considerable distance from the nest (200+m). Given the wide-angle fixed lens of the camera, at this range it was difficult to detect on the images any hen harrier movement. Sightings of birds were infrequent but did occur daily until the final detectable sighting at 07.58 on the 25 June. Thereafter, there were no sightings even on the 26 June when at 07.06 a small herd of sheep passed very close to the nest. It would appear that predation occurred on either the 25 or 26 June when the young were 21-24 days old and a week away from fledging.

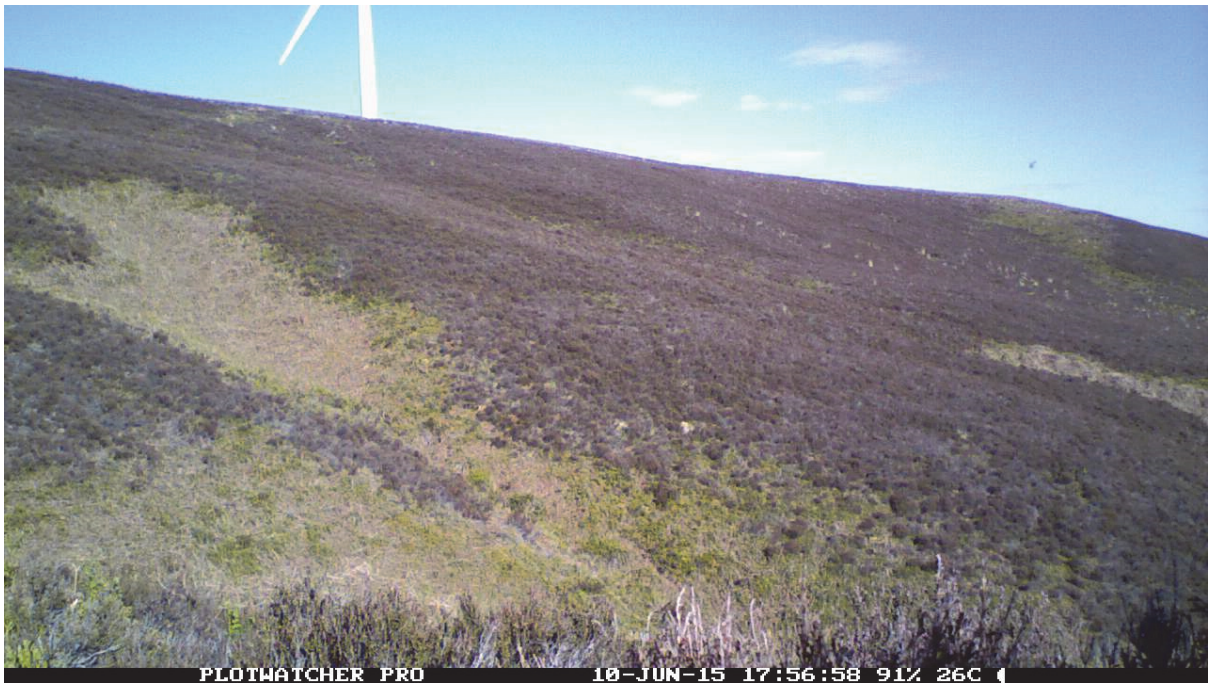

Figure A1. [redacted] 10 June 2015, looking south-east. Hen harrier nest is distant upper right. Note the wind turbine tower on the ridge.

2017. [redacted] estate

Female adult (four + years). Male adult (two + years).
Nest location: [redacted]. In heather on a gentle SW slope below windfarm at 400m.

17 May, 14.00 hours. Female flushed from six eggs. Female very aggressive. Plotwatcher installed at ground level further up slope 35m away.

5 June, 12.15 hours. Female flushed from five eggs and one newly hatched chick. Nest camera installed. Female watched back to nest.

30 June, 12.48 hours. Nest predated, lots of splash from the chicks. Remains (part grown wing quills) of one chick and three broken addled eggs in nest. Second chick found partially buried 2m away. Fox predation suspected.

Nest camera: 24,356 images from 5 June to 11.40 hours on 14 June when batteries failed. Last images show three downy young and three unhatched eggs in nest (Figure A2)

Figure A2. [redacted] nest 14 June 2017. Adult female feeding three young. Camera batteries failed soon after. The brood were predated probably by a fox on 28 or 29 June.

Plotwatcher camera. 371,152 images from 17 May to 30 June. The view of the nest was restricted due to ground vegetation. HH activity recorded on all days except 30 June. Last sightings were of a female taken on the 29 June at 06.23, 08.27 and twice at 08.29. No further sightings thereafter. There are only a few images on the 28 June and none in the afternoon or evening suggesting the predation event could have occurred at any time on these two days. The appearance of the female on the morning of the 29 June may have been her carrying out a final check of the predated nest.

Figure A3. Distant camera view of [redacted] *nest, 10.40am on 28 June 2017. Nest is in the centre middle ground. Female Hen harrier approaching on the far right. The nest was predated sometime in the next 24 hours.*

2017. [redacted]

Age of breeding birds unknown.
Nest location: [redacted]. 510m facing south-west. Tall heather in steep valley side.

10 May. Nest located by raptor study group member when it contained three eggs. No cameras installed.

14 June. Nest empty. Lots of splash around flattened nest suggesting it had young. Pulled out body down from small chick found in heather 10m downhill of nest suggesting brood removal by ground mammalian predator.

2018. [redacted] estate

Female age first year. Male age unknown. Nest at [redacted] in long heather close to recently constructed hill track on west facing hillside overlooking extensive flat area. Nest located by raptor study group member.

26 June, 13.20 hours. Female flushed from five eggs. Ltl Acorn camera installed at [redacted]

2 July, 11.20 hours. Female flushed from five eggs. Lots of down from female adhering to heather. Ltl Acorn camera replaced with Plotwatcher.

11 July, 11.15 hours. Female flushed from two newly hatched chicks (shells still present) and three eggs.

17 July, 11.30 hours. Two tiny runt chicks and two eggs. Female overhead with prey. Nest camera installed. First-year male from nearby nest alarming and escorted me up the track but returned to primary nest.

24 July, 10.30 hours. two cold eggs (both addled). No chicks. A little splash. No adults seen. All cameras removed. Plotwatcher camera, 224,640 images from 26 June – 24 July.

Figure A4. [redacted] estate, 19 June 2018, looking south. The hen harrier nest is directly below the bird on the nearest ridge.

Nest camera, 20,800 images from 17-24 July.
From the examination of the images it was soon apparent that there was no male provisioning the female and what little food that came to the nest was what the female obtained herself. It is possible that the first-year male at the nearby harrier nest was the bigamous mate. This would explain the late start to breeding and the lack of support this nest received during a critical period.

The camera was installed at 11.20 on 17 July and during the day no prey items were seen being fed to the two chicks. The 18 July was the same despite the chicks seen begging for food twice. The female's response was to leave the nest and return with fresh nest material. During the afternoon she was away from the nest for two one-hour periods but only returned with heather twigs. The weather during the day was hot with light winds.

The 19 July brought a change when the female returned with a large plucked red grouse. The chicks initially showed no interest (too weak?) but at 09.57 the eldest of the two accepted food from the female in a short feeding session. The female then flew off with the partially eaten grouse and returned at 11.30 with the prey but did not feed the chicks. The smallest chick by now appeared lifeless. Over the next five hours the female went to and from the nest with the grouse. Finally, at 16.37 she began feeding the eldest chick until it was satiated. She left again with the prey remains at 16.47, returning to brood both chicks. At 18.16 she suddenly stood up and picked up the youngest emaciated chick in her bill (Figure A5) and flies off with it. On her return the female brooded the surviving chick through to the following day.

Figure A5. [redacted] *estate, 19 July 2018. Female hen harrier removing dead chick from nest. It had died from starvation the previous day.*

On the 20 July the female brought in the first and only prey item of the day, a large grouse chick at 13.02 but did not feed the chick until 14.26. This feeding session lasted nine minutes. The grouse is then removed from the nest but is brought back at 16.10 for a second feed which ends at 16.18. There are no further feeds. The chick is brooded through to the following afternoon on 21 July. The female harrier is away from 13.05 to 17.50 with only two brief visits with nest material. Finally, at 17.52 she brings back the grouse remains to the nest and appears to feed the chick for three minutes before flying off with the grouse again, returning to brood the chick through to the following morning.

The 22 July is another clear hot day. The female left the nest at 09.14 and returned at 13.18 without any food. The chick has shown little movement during her four-hour absence. The female commences brooding at 13.30, but at 14.15 she stood up and picked up the chick (Figure A6), now clearly dead, spending five minutes touching it with her bill and moving it round the nest. Finally, at 14.21 she pulled at the abdomen with her bill tearing the skin and

exposing the intestines (Figure A7). She immediately departs with the chick returning without it at 14.34. She then left the nest at 14.37 but then returned briefly five times up until 21.39. Her last brief visit to the nest is at 05.48 on the morning of the 23 July. She does not appear on camera again.

Figure A6. [redacted] *estate, 22 July 2018. Female harrier retrieving dead chick, the last in the brood.*

Figure A7. [redacted] *estate, 22 July 2018. Female harrier pulling at skin of dead chick exposing the intestines before flying off with it.*

2018. [redacted]

Female age first-year, male age first-year. Nest location [redacted] on east facing gentle slope in long heather that had been burnt five years previously with much green regeneration.

16 May, 15.00. First year male chased red kite at 16.35 and then food passed to female at 16.50. Female watched back to nest, three eggs. Plotwatcher camera installed at [redacted]

1 June, 19.30. Nest checked, four eggs (very warm). Both birds alarming.

21 June, 15.30. One young (five days) and one dud egg. Acorn nest camera installed.

6 July, 10.30. Chick missing. Chewed quills nearby. Dud egg opened up and nest lining disrupted. Both cameras removed.

Plotwatcher camera. 345,600 images from 15 May to 6 July.

Figure A8. [redacted] *estate 2018 looking east. Hen harrier nest is low centre.*

Nest camera. 12,144 images from 21 June to 6 July.
The nest camera revealed a single chick being reared up until the evening of the 5 July. The chick was fed at 19.43 (Figure A9) and was then brooded by the female. A fox predation event occurred during the night at 01.44 (Figure A10). Moments before, the female hen harrier had been brooding the chick. She left just before the fox's arrival. The fox spent a minimum of 18 minutes in the vicinity of the nest consuming the chick before finally leaving. The female harrier did not land at the nest again.

Figure A9. [redacted] estate, 5 July 2018, 19.43 pm. One-year old female hen harrier feeding single chick. The chick was predated by a fox six hours later.

Figure A10. [redacted] estate, 6 July 2018, 01.44 am. A red fox arrives at the nest and predates the single chick.

2018. [redacted]

Female age unknown. Male age adult (2+ years). Nest location [redacted]. Tall heather on steep sided side of valley. 450m facing south-west. This site was occupied by breeding hen harriers in 2017 and the nest also failed for an unexplained reason.

24 May, 10.30. Nest visited, female incubating four eggs. Plotwatcher installed.

9 June, 12.00. Nest empty. Deep cup, no splash or egg fragments suggest that no young were ever present.

Figure A11. [redacted]*, 24 May 2018. Raptor Study Group member, Dave Pierce, stood by the Hen harrier nest with four eggs. A gamekeeper's house is in the background.*

Plotwatcher camera. 129,600 images from 24 May to 9 June.
Clear skies and light winds dominated the weather during this period. There were regular daily images of both the male and female hen harriers up until the evening of 5 June. Thereafter, no further images of the harriers appear. The loss of the clutch of eggs likely occurred during the night of 5/6 June. The cause of this egg loss or the predator involved is unknown.

2018. [redacted]

Female first-year. Male first year. Nest at [redacted] in deep heather on steep hillside in unplanted area within large pine-wood enclosure with deer fence. 514m west facing.

24 May, 12.15. Nest visit. Female flushed from five eggs. Plotwatcher installed.

16 June, 14.45. Nest visit. Female flushed from five eggs. Both male and female perched on nearby fence posts.

23 June, 11.25. Nest visit. Female flushed from one newly hatched chick and one watery egg. Large hatched egg shell from chick still in nest. First-year male alarming.

30 June, 11.00. Nest visit. One dud egg. No sign of missing chick. Plucked feathers of meadow pipits in nest and fine shell fragments. No parent birds seen. Plotwatcher removed.

Plotwatcher camera. 311,040 images 24 May to 30 June.
Hen harriers appear infrequently on camera. It was possible for harriers to approach and leave the nest without being seen from the position of the Plotwatcher camera which was partially screened by tall heather. Following the nest visit on the 23 June there are just two images showing harriers, at 14.59 and at 21.07 when two birds appear in the distance. However, at 18.21 and twice at 18.25 an adult gull either a herring *Larus argentatus* or a common *Larus canus* can be seen flying in the vicinity.

There are no further images either of hen harriers or potential nest predators over the following seven days.

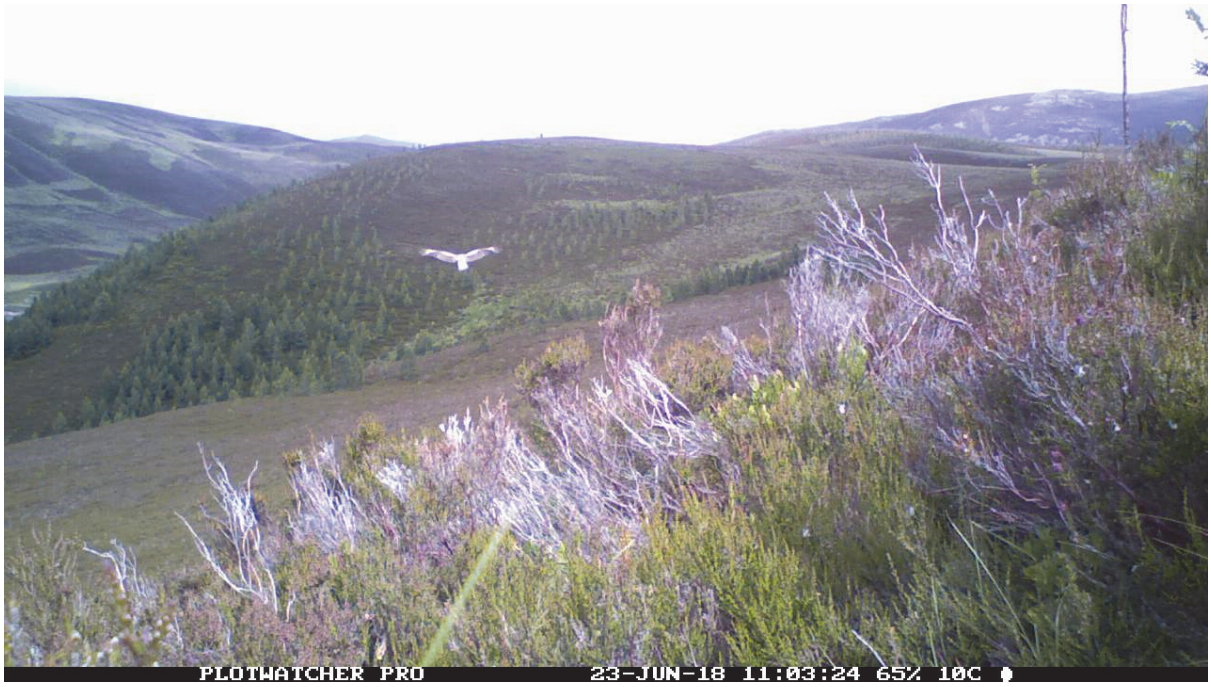

Figure A12. [redacted]*. 11.03, 23 June 2018. First-year male hen harrier over nest site on hillside. This was the best of a small number of images of harriers obtained from this view point.*

2019. [redacted]

Female age unknown. Male age adult (2+ years). Nest location at [redacted] in deep heather half-way up very steep exposed SW facing slope at 520m, the highest nest visited. Within 50m of a successful nest in 2018.

31 May, 10.00 hours. Female harrier flushed off five eggs. Plotwatcher camera installed on 3m high scots pine slightly above and 25m from nest (Figure A13).

16 June, 13.15 hours. No adults seen. Nest contained three eggs, cold and apparently deserted. Shell discolouration indicated desertion was not recent. One egg opened and contained partial grown embryo. No signs of any hatching.

Plotwatcher camera. 138,240 images from 31 May to 16 June.
They show harrier activity during 31 May to 2 June. Weather throughout this period windy with lots of showers, heavy at times coming from the SW. The weather on the morning of 2 June particularly poor with rain and low cloud driven by a strong SW. Nest slope badly exposed. There was an unusual cluster of images showing harrier activity during late morning and early afternoon. The female harrier is off the nest at 11.01, 11.02, 11.33, 11.34, 13.34 and 13.35. The male appears at 11.02, 11.36 and 12.48. There is only one image showing activity on the 3 June, a male appears in shot higher up the slope at 14.11. Finally, on the 4 June at 08.39, the female with tail fanned is photographed flying over the nest (Figure A11). Hen Harriers do not appear in any of the further images up to the 16 June.

The cause of the failure could not be determined but may have been nest desertion associated with the poor weather on the 2 June.

Figure A13. Distant view at [redacted]. *Final image of a hen harrier over the nest location at 08.39 on the 4 June 2019. It is believed the nest had failed earlier.*

2019. [redacted] estate

Female age unknown. Male age adult (2+ years). Nest location [redacted], 166m, facing south. Steep rank heather slope on northern edge of strath.

19 May, 13.30. Food pass. Nest visited, flushed female, 4 eggs. Plotwatcher installed (Figure A14).

31 May, 13.00. Nest empty. One broken egg 1m downhill of nest on mammal track. No shell fragments or chick droppings in nest. Plotwatcher removed.

Figure A14. Female Hen harrier over nest slope. [redacted] estate, 20 May 2019. The nest is bottom right just above a line of large rocks. The date and time recorded in this image are corrupted. The camera later shut-down.

Plotwatcher camera. 25,920 images from 19-21 May.
The camera recorded images for 48 hours covering three different days before stopping for an unknown reason. The date and time recorded on all images were incorrect.

The failure of this nest during incubation could not be explained from the limited images available. This hillside is a regular, almost annual, nesting site for hen harriers going back to the late 1980s when the strath was first visited by BE. A pair bred successfully here in 2018.

2019. [redacted] estate

Female age unknown. Male age adult (2+ years). Nest location [redacted], 360m facing south-west. The same slope as that in Figure A1.

Two large wild fires engulfed this estate in the spring of 2019. In late-April backed by southerly winds a massive fire destroyed 27 square miles of moorland, one of the largest wild fires experienced in the UK (Figure A15). A second fire destroyed neighbouring woodland and moorland in mid-May. Both fires prevented access to [redacted] until the risk was considered minimal.

The first visit was not made until the 22 June. Almost all heather covering [redacted] and neighbouring [redacted] had been destroyed. However, the heather slope shown in Figure A1 below one of the turbines had survived intact. After a short watch and adult male hen harrier arrived and food passed to a female. She was watched back to a nest containing two badly soiled eggs that looked like they had been incubated for a considerable time, far more than the normal 30 days. No cameras were deployed.

The nest was re-visited on the 5 July. The two eggs were cold and appeared deserted. No adults were seen. The impact of the fires and smoke in the vicinity and the presence of a large team of fire-fighters over an extended period in the spring could have kept the harriers from attending the nest and contributed to the nest's ultimate failure.

Figure A15. Wildfire engulfing [redacted] estate, 27 April 2019. It took five days to extinguished this fire. It flared up again or was re-started in mid-May destroying further moorland and forestry.

ANNEX 2. PREY AND PREY PROVISIONING

In common with other harrier species, only female hen harriers incubate the eggs and later brood and feed the young, it is rare for males to do so (Figure 5). The role of the male is to hunt and deliver prey either via an aerial food pass to the female or via a food drop into the nest (Figure 1). As the young grow this can change. Depending on the number of young and the skill and efficiency of the male, the female's role may increasingly involve hunting and less as nest guardian (Hardey *et al., 2013; Watson, 1977)* (Figure 7).

The *Heads up for Harrier*s remote nest cameras provided an opportunity to investigate prey species and provisioning. The cameras images recorded all prey deliveries at the nest, the date and time of delivery and provided an estimate of the size of prey. For bird prey, the age and species could often be identified. Previous studies of hen harrier prey species and delivery have been largely based on short-term hide-work and pellet and prey remains found in nests (e.g. Picozzi, 1978; Redpath *et al.,* 1997; Leckie *et al.,* 2008). The continuous use of trail cameras at multiple nests has been reported once before (Fernàndez-Bellon *et al., 2017*) but for relatively short two-week periods during the chick rearing.

Over two million images were recorded at 37 nests over the five years. Due to time constraints, images from just six nests covering 91,012 images over 39 days in four different years were looked at. The images at the remaining 31 nests await analysis in the future. From the six nests, a total of 493 prey deliveries were recorded (Tables A1 & A2).

Bird species dominated the identified prey brought to nests (Table A1) constituting 89.4% of all deliveries with mammals nearly 10.0% and amphibians 0.6%. These percentages were very similar across the four moorland managements looked at. Of the birds, small passerine birds featured most, particularly meadow pipits amongst those that could be clearly identified. Meadow pipits are an abundant moorland species and at 87%, dominated the small and medium size passerine prey recorded at nests (Table A2). It is likely pipits formed a similar proportion (142) amongst the 152 unidentified small and medium size passerines recorded. Making this assumption, meadow pipits would represent 77% of 305 birds recorded. Red grouse featured 17 times in 305 bird prey items (5.6%) but rose to 17.5% amongst all prey at the one driven grouse-moor examined. Picozzi (1978) from over 750 prey items at nests on a Kincardineshire grouse moor had a similar bird/mammal ratio, though grouse at 34% featured more prominently. With lagomorph prey, it was not possible to identify the species as only dismembered portions were brought to the nest. In mass alone they were an important item, particularly so for the larger broods.

The 2017 [redacted] nest

This nest received the longest nest camera coverage extending from part-way through clutch incubation and throughout hatching, chick rearing and fledging. A nest camera had been installed early to detect the cause of any further egg loss after the clutch underwent a reduction from five to three eggs between visits five days apart. The female was a first-year bird and the male in his second year due to the presence of un-moulted brown juvenile feathers in his adult type plumage (Figure 5). No further losses occurred and all three eggs hatched and three young fledged. The early presence of a nest camera allowed provisioning by the male to be recorded during incubation as well as deliveries throughout the chick stage.

Prey delivery during incubation

The camera was installed at mid-day on the 8 June. The clutch of three eggs was incubated for a further six and half days before the first chick hatched. Over five full days the female was provisioned by the male on three to five occasions (average 3.8, but on one day 10 times), between the hours of 05:40 and 21:29 BST, mainly 08:00 – 20:00. The female harrier consumed all prey away from the nest which could not be identified apart from the

day before the first chick hatched when she brought three prey items back to the nest in the afternoon and early evening (young blackbird, skylark and vole sp.). This was probably a response to the chick calling from inside the first egg which was close to hatching.

Prey delivery during chick rearing

The [redacted] nest was the only one where the hatching of a clutch was fully covered by camera. Prey delivery during the first seven days after the first hatching was examined, plus further days at the 17-19 and 33 & 34-day points. The first chick hatched in the early hours of the 15 June and received its first feed at 08:57 on day one. The second chick hatched three-days later, again in the early morning. The third hatched in the late afternoon on the fifth day. All three chicks fledged successfully despite the four-day age difference.

Days 1-7. On the first day, the male visited the nest on four occasions when the female was absent following a food-pass. The duration of the visit varied from 1-9 minutes and he was photographed brooding during the longest spell (Figure 5), the only time any male over the five-year study was recorded doing this. His response to the presence of chicks was to increase prey provisioning immediately to eight items on day one and to 10-12 prey items on days 2-7. Prey items were all small, dominated by passerine birds consisting mainly of meadow pipits, with smaller numbers of voles *Microtus* species.

Days 17-19. By this stage in chick development, the female had started hunting and prey provisioning increased to 19-23 (average 20) small prey items a day mostly delivered between 06:00 and 20:00 daily in a 13-14-hour period.

Days 33-34. At this stage the young were fully feathered and the two eldest had fledged though they spent long periods in the nest waiting for prey drops by the parent birds. Nine prey items were recorded on day 33 but there were 18 the following day. There were no large prey species such as grouse, rabbits or waders. All were small prey species, mainly passerine birds.

[redacted], 2016

Both parent birds were a minimum of two (male) or four (female) years old. The nest contained five young aged 6-9 days when the camera was first installed. Images from camera days 2-6 were examined. Both the male and female were hunting. Prey provisioning were 28, 32, 28, 17 and 20 items per day respectively. Camera days 2-3 were wet and cool and the female increasingly spent time brooding rather than hunting during this period. Prey items were all small, mainly passerine birds such as meadow pipits. The only large items brought to the nest were four birds, one identified as a lapwing. All four were brought to the nest by the female on days 4 and 5.

[redacted], 2017

The parent birds at this nest were both in adult plumage. The camera was installed when the nest contained a single egg and four young, 1-3 days old. Images were examined on camera days two and three and again on camera day 21. On camera day two, 16 prey items were delivered by the male and 15 the next day by which time the single egg had hatched. All prey over these two days consisted of small birds ranging from fledglings to full-grown individuals in the 15-20g weight range. They were brought to the nest between 05:30 and 19:30 in a 12.6 and 13.6-hour period. On camera day 21, the brood of five were 18 to 23 days old. They were provisioned by both parents on 24 occasions between 06:00 and 22:00 in a 16-hour period. Two prey items were large and unidentified, the rest were small birds.

[redacted], 2018

The heather moor on this estate is sandwiched between the driven grouse-moors of Cawdor on one side and Lochindorb on the other. The pair of breeding hen harriers were both one-year old, the male still in the juvenile ring-tail plumage. They hatched and fledged four young. The nest camera was installed on the 18 June at 16:30 when the four young were 4-6 days old. Prey provisioning was examined over a 3-day period from 19-21 June. Over the

first two days 13 and 14 prey deliveries occurred primarily of small items such as passerine birds. On day three the provisioning increased sharply to 23 items as the female spent increasing time away from the nest. Amongst the 50 prey items delivered over the three days, only two were identified as red grouse, both were chicks, this despite the close proximity of two driven grouse-moor estates.

[redacted], 2018

The pair consisted of a one-year old female and a grey plumaged male that was a minimum two years old. Of the six eggs laid, four hatched and fledged. On this driven grouse-moor, lying immediately to the east of Lethen estate moor, the nest camera was installed when the young were two to five days old. Data from the images were examined on camera days two and three after installation and again on camera days 13 and 21. On camera days two and three, 14 and 11 prey items respectively were brought to the nest by the male, three of them were grouse chicks during 13.5-hour periods. On day 13, provisioning had increased to 20 items over a 10.4-hour period, this despite a delayed start to prey deliveries possibly due to wet weather in the early morning. Five grouse chicks and part of a hare or rabbit were the largest prey brought to the nest during the day. Amongst the eleven deliveries on day 21 were two large portions of lagomorphs and two grouse chicks. The rest were small passerine birds.

[redacted], 2019

Another one-year old female breeding for the first time with a grey plumaged male at least two years old (Figure 7). The nest originally contained six eggs when first visited on 21 May. On the next visit on the 16 June the female was brooding a single five-day old chick. There was no signs or indications of the fate of the missing eggs or chicks. There was considerable potential disturbance throughout June and July from work with heavy machinery on a water abstraction project on the river below and within 200m of the nest. This may have exposed the nest to partial predation or chick mortality if the female hen harrier was disturbed from the nest for long periods.

Images were examined for a three-day period, 26-28 June, when the chick, sexed as a male, was 15-17 days old. On day one he received five prey deliveries, all from the female. The first two in the morning at 07:26 and 08:01 were large – the rear hind legs of a lagomorph and a medium sized grouse chick. After the second feed the female left the nest and was absent for seven hours returning in the mid-afternoon with a small bird. Two further small birds were delivered by the female in the early evening. The second day brought nine prey deliveries, all small items, and again the female was absent for six and a half hours during the day. On the third day, five prey items were delivered, including two grouse chicks (Figure 1).

Table A1. Abundance of birds, mammals and amphibians as prey at six hen harrier nests under differing moorland management, 2016-2019.

Taxon	No grouse-shooting		Walked-up shooting		Driven grouse-shooting		Conservation moorland		Moorland Total	
	n	%	n	%	n	%	n	%	n	%
Birds	214	89.5	38	90.5	38	86.4	15	93.8	305	89.4
Mammals	24	10	3	7.1	6	13.6	1	6.2	34	10.0
Amphibians	1	0.4	1	2.4					2	0.6
Identified prey total	239	65.1	42	84	44	77.2	16	84.2	341	69.2
Unidentified prey total	128	34.9	8	16	13	22.8	3	15.8	152	30.8

Table A2. Species composition and numbers brought to six Hen Harrier nests as prey, 2016-2019.

Species	Estimated weight (g)	No grouse shooting	Walk-up shooting	Driven grouse shooting	Conserv-ation moorland	TOTAL
Unidentified prey						
unknown size		24				24
small item	15	104	8	12	3	127
medium item	50			1		1
Unidentified total		**128**	**8**	**13**	**3**	**152**
Unidentified birds						
small bird, nestling	15	15		1		16
medium bird, nestling	30				2	2
small bird, full-grown	18	114	12	7	5	138
medium bird, full-grown	50	3	3	1		7
large bird, full-grown	150	4	1			5
Meadow pipit, nestling	15	22		9	1	32
Meadow pipit, full-grown	18	42	14	9	3	68
Skylark	33	2	3			5
Pied wagtail	23	1				1
Stonechat	18		1			1
Song thrush	70	2				2
Blackbird	100	1	1			2
Lesser redpoll	11	1				1
Warbler species	10	3				3
Snipe, large chick	80			1		1
Small wader chick	20	2	1			3
Lapwing	200	1				1
Red grouse, small chick	25	1	1	2	2	6
Red grouse, poult	150		1	8	2	11
Bird total		**214**	**38**	**38**	**15**	**305**
vole species	27	16	2			18
shrew species	9			1		1
Small rabbit/hare	200	6	1	5	1	13
Small mammal	30	2				2
Mammal total		**24**	**3**	**6**	**1**	**34**
Amphibians - frog	22	1	1			2
GRAND TOTAL		**367**	**50**	**57**	**19**	**493**

ANNEX 3. DETAILS OF TWO RINGED HEN HARRIERS FOUND BREEDING

Bird one
Ringing details
Ring number: FB14422
Age/sex: nestling female
Brood size: 3
Ringing date: 15 July 2016
Ringing place: [redacted], Moray. NJ03
Ringer: [redacted]

Finding details
Age/sex: first-year female
Activity: breeding
Finding date: 15 June 2017
Finding place: [redacted] Highland. NH79
Duration: 335 days Distance: 66 km.
Finding details: Metal ring read in field (nest camera)

Bird two
Ringing details
Ring number: FC60594
Age/sex: nestling female
Brood size: 6
Ringing date: 15 June 2017
Ringing place: [redacted], Highland. NH52
Biometrics: Wing 132 mm. Weight 460 g. Time 22.00 hours.
Ringer: Brian Etheridge

Finding details
Age/sex: first-year female
Activity: breeding
Finding date: 26 Jun 2018
Finding place: [redacted] Moray. NH93
Duration: 376 days Distance: 41 km.
Finding details: Metal ring read in field (nest camera)

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