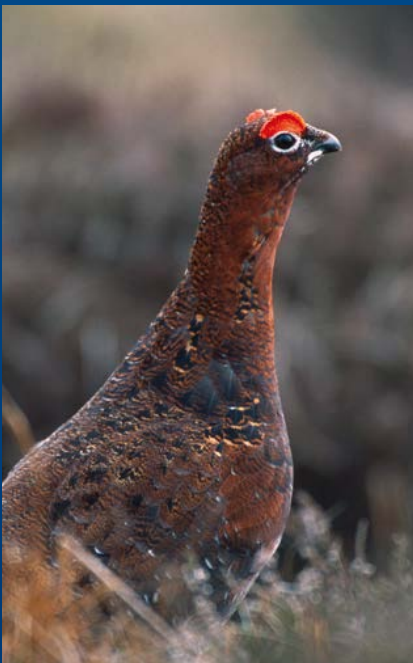
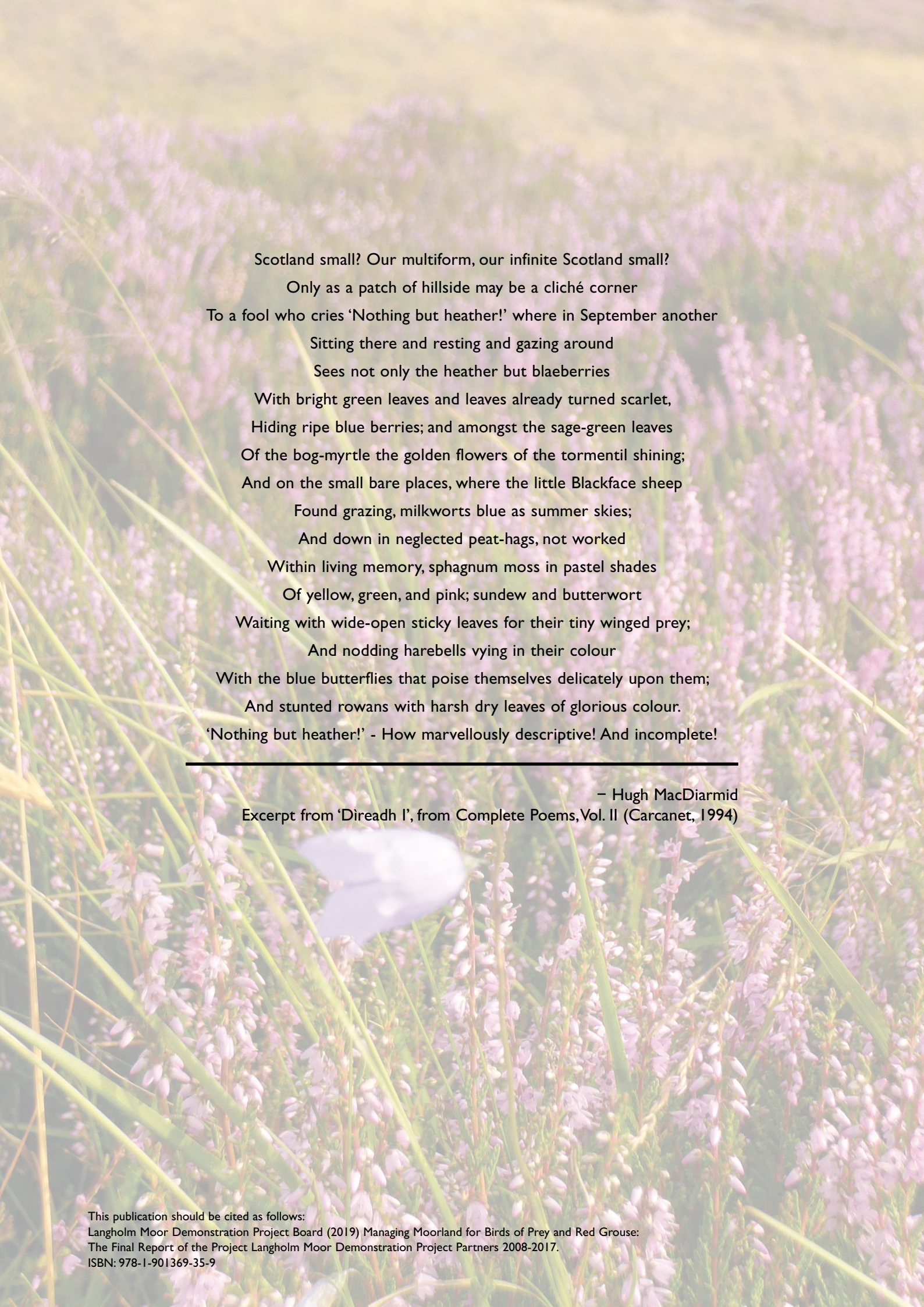


MANAGING MOORLAND FOR BIRDS OF PREY AND RED GROUSE

The Final Report of the Langholm Moor
Demonstration Project Partners
2008-2017





Scotland small? Our multiform, our infinite Scotland small?
Only as a patch of hillside may be a cliché corner
To a fool who cries 'Nothing but heather!' where in September another
Sitting there and resting and gazing around
Sees not only the heather but blaeberreries
With bright green leaves and leaves already turned scarlet,
Hiding ripe blue berries; and amongst the sage-green leaves
Of the bog-myrtle the golden flowers of the tormentil shining;
And on the small bare places, where the little Blackface sheep
Found grazing, milkworts blue as summer skies;
And down in neglected peat-hags, not worked
Within living memory, sphagnum moss in pastel shades
Of yellow, green, and pink; sundew and butterwort
Waiting with wide-open sticky leaves for their tiny winged prey;
And nodding harebells vying in their colour
With the blue butterflies that poise themselves delicately upon them;
And stunted rowans with harsh dry leaves of glorious colour.
'Nothing but heather!' - How marvellously descriptive! And incomplete!

– Hugh MacDiarmid
Excerpt from 'Dìreadh I', from Complete Poems, Vol. II (Carcamet, 1994)

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Acknowledgements

The directors of the LMDP would like to warmly thank Simon Lester who led the gamekeeper team, the scientists and students, notably Damian Bubb and Sonja Ludwig, and the project manager Graeme Dalby, all of whose hard work and commitment over the years made this project possible. The directors would also like to thank the chairman and members of the Scientific & Technical Advisory Group (Jeremy Greenwood, Alex Jameson, Ian Newton, Bryan Burrows, Simon Thirgood, Steve Redpath, Mick Crawley, Alan Edwards, Lindsey Waddell, Robert Kenward, Simon Thorp) and the Science Contact Group (Nick Sotherton, David Baines, Staffan Roos, Jeremy Wilson, Des Thompson, Stephen Murphy) who gave their time and expertise. Thanks go to the many members of staff in the partner organisations who have provided support and back up to the LMDP notably the Langholm Initiative, the local Raptor Study Groups and other volunteers who have helped with monitoring. Finally we offer our grateful thanks to the project's funders.



Some of the Project team. From Left to Right: Sonja Ludwig (project scientist), Simon Lester (head gamekeeper), Mark Oddy (project director, Buccleuch), Duncan Orr-Ewing (project director, RSPB), Graeme Dalby (project manager), Susan Davies (project director, SNH 2010 - 2013), Teresa Dent (project director, GWCT).



“
...the time was right for solutions to
the perceived conflicts to be tested.
”

Foreword

Many people who wanted to see a bright future for our moors visited the Langholm Moor Demonstration Project (LMDP) over its 10 years. They were drawn to this moor by three things: its history, their desire for this wildlife conflict to find resolution, and the new approach being trialled.

The approach to the project was remarkable for being both a partnership and based on the principles of demonstration. Partnership brought together the landowner, agencies, specialist organisations, volunteers and students. The range of views represented was a deliberate signal of intent that moorlands have much to offer many diverse interests. The focus on demonstration (rather than on further research) underpinned by monitoring, indicated the time was right for solutions to the perceived conflicts to be tested.

The conflicts have been framed thanks to the unique historical legacy of Langholm moor as a site of research into moorland management for red grouse. The Joint Raptor Study (1992-1997)¹ showed how predation by raptors could prevent the recovery of a red grouse population. The concomitant rise of the hen harrier population led to the moor being designated as a Special Protection Area (SPA) for the species. But without grouse to shoot, the moorland gamekeepers were withdrawn and by the early 2000s too many aspects of Langholm moor were in decline: heather habitats were receding, mountain hares were extinct, there was no grouse shooting, hen harrier and wading bird numbers had collapsed and the local communities were less engaged with and benefiting from the moor.

There was an urgent need to seek solutions to these problems. In 2000 the DETR Raptor Working² Group made recommendations for raptor conservation, recognising the role managed grouse moors had to play. A desire to recover Langholm moor as a local and national asset and address fundamental questions around the balance of moorland management drove the intent shown by the partnership. Could management for red grouse restore the moor's habitat quality back to the levels celebrated in verse by Hugh MacDiarmid? Would this management support and enhance bird of prey populations? Would other biodiversity benefit? Could red grouse respond to management, and what new and adaptive management might be needed? And critically could the support system for this management, the financially viable driving of grouse for shooting, be compatible with resilient bird of prey populations?

These were fundamental issues for Scotland's moors in 2008, when this project started, and were captured in the 'Statement of Intent' from Scotland's Moorland Forum in 2007. They are as, or more, important now. During my chairmanship of Scotland's Moorland Forum, which spanned the life of the LMDP, I was privileged to see the way in which many moors addressed the challenges they faced. Some challenges are as a result of changing land use, as grazing pressure increased or decreased, and as forests and woodlands expanded, separating moors from each other. In other places the pressure exerted by predators on ground-nesting birds was the critical issue. Langholm moor brought these issues together and crystallised the drive for solutions. The legacy of this project, and those that preceded it, should be clear to all those who, like me, value our heather hills.



LORD JAMIE LINDSAY

CHAIR OF SCOTLAND'S
MOORLAND FORUM
2007-2018

A handwritten signature in black ink that reads "Jamie Lindsay".

Opposite Page: Grouse feather in heather.
© Adam Smith

Chairman's Report



MARK ODDY
LANGHOLM MOOR
DEMONSTRATION
PROJECT CHAIRMAN
SEPTEMBER 2019

I am pleased to bring you the final report of the Langholm Moor Demonstration Project (LMDP). This report follows the Project's Seven Year Review we produced in 2014³ (Executive Summary in Appendix 1), and I recommend that those who want to fully understand the project read both.

The project's business and operational structures, including the board, management, gamekeeping, monitoring and the 'Science and Technical Advisory Group' and information about activities and outcomes such as published papers are given on the website: www.langholmproject.com

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Capsule:

- The Langholm Moor Demonstration Project's (LMDP) main objective was to establish Langholm Moor as a driven grouse moor and to meet the nature conservation objectives for the Special Protection Area and Site of Special Scientific Interest.
- The project was funded and delivered by a partnership of Buccleuch, Scottish Natural Heritage, Game & Wildlife Conservation Trust, Royal Society for the Protection of Birds and Natural England from 2008, employing gamekeepers to deliver grouse moor management practices until 2016 and a science team to monitor these effects until 2017.
- Individual elements of the project were markedly successful: addressing decades of heather loss, the subsidised grazing removal and gamekeeper management recovered overgrazed moorland and reduced predation on ground-nesting birds, allowing some recovery of their populations.
- The project has provided insight for thousands of visitors into raptors' relationships with prey, the rate of recovery of heather habitats from grazing pressure and the economic cost of maintaining heather moors.
- However, the gamekeeper management which brought these positive outcomes could not be afforded in the long run because there were insufficient grouse available to be shot in order to achieve the chosen economic return.
- The available data indicate that at Langholm a longer period of time, managing a greater area of heather habitat in the same way would be unlikely to achieve the chosen economic return from grouse shooting because grouse were not breeding sufficiently well. For this moor further reductions in predation pressure would probably be required to achieve and maintain the project's target for grouse numbers.

1. Objectives and aims:

The Langholm Moor Demonstration Project was set up to test whether we could achieve a 'win: win', where breeding raptors co-existed with commercial driven grouse shooting³. The main objective was *"to establish Langholm Moor as a driven grouse moor [and] to meet the nature conservation objectives for the SPA [Special Protection Area] and SSSI [Site of Special Scientific Interest]"*. The project had four deliverables:

- A demonstration of how to resolve conflicts between moorland management for raptors and red grouse;
- That the hen harrier population would be maintained as a viable component of the SPA;
- That heather moorland habitat would be extended and improved beyond its state in 2002;
- That the number of red grouse shot would be sufficient to ensure the moor reaches a financially viable state.

Progress was assessed by tracking the changes in: heather moorland habitat, red grouse numbers, hen harriers and other raptors, wildlife (passerines, waders and voles), management for raptors and red grouse, and stakeholder engagement and influence. 'Objectives and Progress' on pages 12-13 summarises the project's aims and achievements.

2. Site context:

Langholm moor (**Figure 1 overleaf**) has become a focus for stakeholders in moorland management. It was a former driven grouse moor and it is a Special Site of Scientific Interest (SSSI) for upland habitats and breeding birds including hen harriers and a Special Protection Area (SPA) for hen harriers. By the mid 2000's these interests needed restoration and it was felt that grouse moor management could provide the means. There were historical datasets for habitat, raptors, grouse, wading birds and other prey that provided baselines from which to track responses to management^{1,19,20} (**Figure 2 overleaf**).

Langholm is a large, relatively isolated moor which by 2007 had restricted heather cover and low grouse densities^{7,8}. As national policy targets are for woodland cover to increase, potentially isolating moorlands, studying management effects on such a moor has become highly relevant to wider moorland sustainability discussions which include the role of predator control, hill farming and peatland management¹⁸.

3. Management:

LMDP managed the moor for grouse shooting which, as with other active moorland conservation approaches, required time, resources and expertise. The management timescale for the project, nominally 10 years starting in 2008, was typical of the timescale over which a commercial grouse moor tenant or new owner might try to recover a moor for driven shooting. Five gamekeepers and a project manager were responsible for planning and carrying out the hill management over 11,492ha of study area containing ~4,200ha of core grouse beats^{7,8}. The historical keeping density for this moor was one keeper per grouse beat, core beats averaging 1,070ha in size⁷.

Habitat was managed using traditional (grazing control, muirburn, cutting) and novel (spraying and re-seeding heather) restoration methods^{3,8}. Control of worms in grouse and monitoring of tick and tick-borne disease followed best practice guidance and appeared adequate⁹. Legal predator control using shooting, traps and snares reduced the abundance of foxes (by 80%) and crows (by 65%)⁴ until February 2016. Langholm has become synonymous with the diversionary feeding (DF) of harriers, though it remains an uncommon activity on other moors. During this project DF reduced delivery rates of grouse chicks to harrier nests by between 34% and 100%¹⁰. It is a management tool which could reduce the conflict between hen harrier and red grouse interests if grouse productivity is thereby maintained or increased¹⁰, though this did not occur at Langholm.

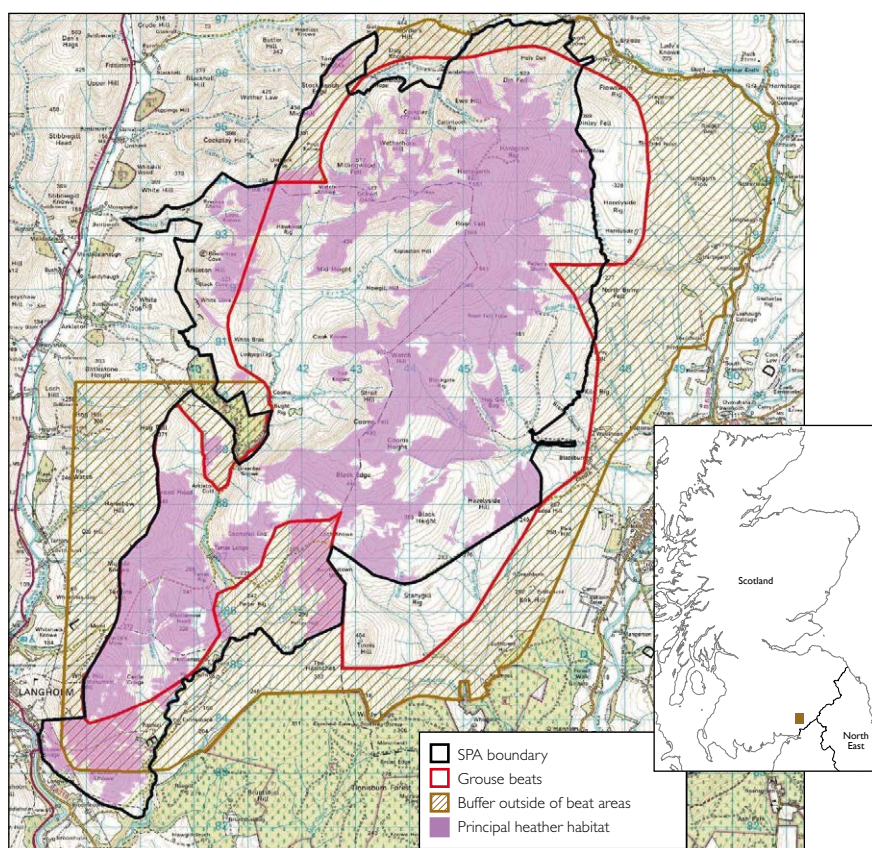


Above: Muirburn and limiting sheep grazing promoted new heather growth © SNH

Figure 1

The Langholm Moor Demonstration Project area (11,492ha within buffer boundary), heather areas, outer boundary of the grouse beats (~6,300ha) and the SPA/SSSI boundaries (~7,800ha) which overlap. The inset map shows the moor's location in southern Scotland. The heather and grass Langholm moor is part of a hill-edge and upland landscape of grass-dominated farmland and semi-natural woodland and conifer plantation.

■ = Langholm moor's location in the north of Great Britain.



4. Public benefits:

LMDP demonstrated how moorland can be managed for red grouse and deliver other public benefits – in this case increased rural employment and biodiversity¹⁸.

The economic activity required was itself substantial and is described in detail in the **'Financial Statement'** section of this report. Between 2008 and 2015 approximately £215,000 was invested annually by partners into employing and equipping five gamekeepers. This represented the income that, were there a reasonable likelihood of shooting, would have come from a tenant and shoot day income. Over the eight years around £1.5 million of capital funds from both public (Scottish Rural Development Programme and SNH) and private sources were reinvested in the moor on fencing, new and upgraded tracks, grazing control and heather reseedling.

The project showed that managing for red grouse can recover and support moorland habitat and species. Some 60 years of heather loss which left only a quarter of the original dominant heather cover was halted. The remaining area of heather-dominated vegetation increasing by 30% over six years to 2,032ha within the buffer boundary⁸, especially after sheep grazing was reduced from 2011. There was an increase in the abundance of birds of prey, perhaps largely because of an abundance of prey^{5,12,13,14,15}. Hen harriers⁴ achieved the project's targets. Harriers and merlins, both ground-nesting raptors, benefited from the project's management which increased prey availability, nesting habitat and reduced the risk of nest predation. Management, especially predator control, contributed to increases in the breeding populations of three wading bird species – curlew, golden plover and snipe – at a time of continuing national decline in their populations⁶. Lapwing numbers did not increase. The fact that wader numbers did not reach their initial project targets may be explained by delayed recruitment within the limited study period and also low initial numbers, low extent of suitable habitat and ongoing predation⁶.

The medium to long-term future for the moorland gamekeeping that supported these changes rested on generating income from driven grouse shooting. This is looked at in the next section.

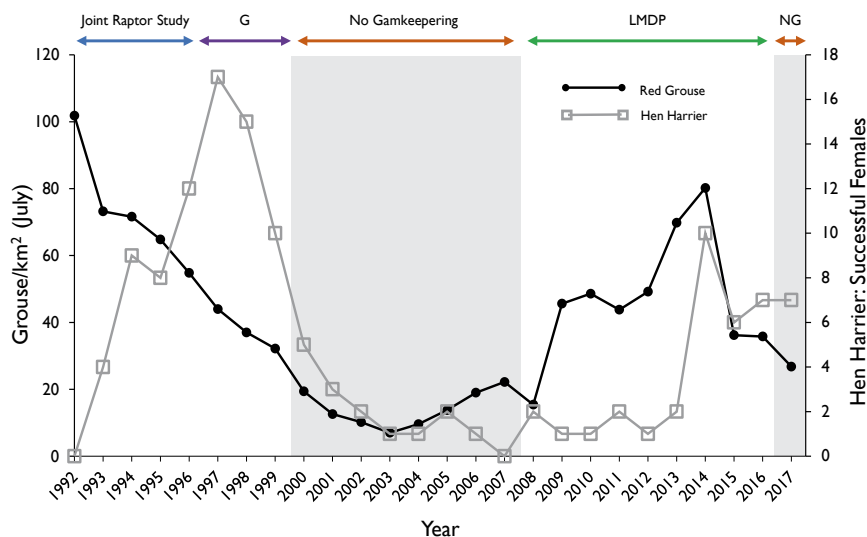


Figure 2

Langholm moor was the location of the Joint Raptor Study (1992-1996) and the Langholm Moor Demonstration Project (2008-2017). In both periods, and from 1997-1999 (G) the moor was managed for red grouse and hen harriers. From 2000-2007 and after February 2016 there was no predator control (No Gamekeeping/NG) on the moor. Sheep grazing pressure was reduced by around half from 2011. The number of grouse per km² in July from block counts and the number of hen harrier females successfully fledging young varied and the most recent analysis⁴ suggests their abundance is related to moorland management activity.

5. Low density grouse population recovery:

The project's business model, 1000 brace shot in at least one of the 10 project years, was a starting point for driven grouse shooting to be the incentive for maintaining moorland management. So it is important to understand why the red grouse did not recover to sustainably shootable numbers.

Red grouse numbers were low at the start of the project (Figure 2). This has an important bearing on the project result because previous work at Langholm showed that raptor predation prevented the recovery of the grouse population from low densities²².

There was a four to five-fold increase in the density of grouse in July from 2008-2014 and then a decline by almost half. The annual increases were inconsistent during the project⁹. Foxes and crows were suppressed, and this activity was linked to the best years for grouse breeding⁴. Grouse nesting success was adequate by the standard of managed grouse moors in all years of the project but chick survival was lower than other studies³. Diversionary feeding of harriers reduced the number of grouse chicks brought to harrier nests by a variable amount, between 34% and 100%¹⁰.

Despite diversionary feeding and the keepers' predator control, the key losses of grouse still appeared to be to predators^{9,11,15} with adverse weather for chicks possibly playing a role in some years^{4,9}. Some 93% of grouse carcasses found showed signs of predation or scavenging (82% raptor; 8% mammal, 3% unknown predator; 7% other) and raptors were associated with 35% of grouse nesting failures⁴. While several factors may influence these rates and their interpretation, the evidence available suggested that mortality associated with raptor signs was the most important factor determining adult survival and was closely linked, possibly alongside weather, to low rates of chick survival⁹.

Habitat is important for ensuring there is the opportunity for the grouse population to expand, but as the project analysis indicated, habitat restoration alone does not improve survival or breeding success so may be insufficient to increase a population that has become constrained by high mortality associated with predation^{7,8}.

6. Grouse shooting:

No grouse were shot during the project^{4,8,10}. In game management a harvest is sustainable if regularly repeatable and it does not in the medium to long term damage the quarry species' abundance or productivity. Each year the project board and gamekeepers, with input from the science team, used the July grouse counts to assess whether shooting should take place. Each year it was felt that adult and chick grouse mortality was too great for there to be 'spare' grouse to be shot in a sustainable harvest⁹. Had shooting taken place in any year the project may have risked 'shooting into [breeding] stock'.

7. Shoot economics:

As there was no realistic chance of sustainably harvesting 1000 brace³ in a season by the end of the project^{9,11}, it was not possible to manage Langholm moor for the desired range of outcomes using driven grouse shooting as the sole or principal source of funding.

Setting a lower grouse bag target would not have altered this outcome for two reasons. First, after allowing for an average annual loss of grouse to other causes, the number of grouse able to be shot without stopping grouse population growth was limited^{8,9,10,11}. Shooting a bag likely to generate enough revenue to sensibly contribute toward the management costs would certainly have been unsustainable. For example, 100 brace of grouse would need to cost £150,000, or £750 per bird (over ten times an average 2019 market price) to cover 50% of the annual management cost. Secondly, the target of 1000 brace shot in a year during the project³ was itself only just enough to attract contemporary investors who balance increasingly high risk and uncertain rewards in game management.

The project cannot offer definitive evidence of the general economic impact of raptors, something which would require experimental approaches. However, there was some work done on buzzards, which found low presence of grouse in individual buzzard diets but large numbers of buzzards hunting on the moor in some years, usually associated with high numbers of voles. Though inconclusive due to the many assumptions involved, simple multiplication of grouse consumption by each individual buzzard suggests that in some years their impact could be high¹¹.

In the absence of grouse shooting and with reduced sheep grazing, the estate and community have relied on Scottish Government subsidy and SNH management income, the habitat, raptor and wading bird improvements being hard to commercialise.

8. Ending project management:

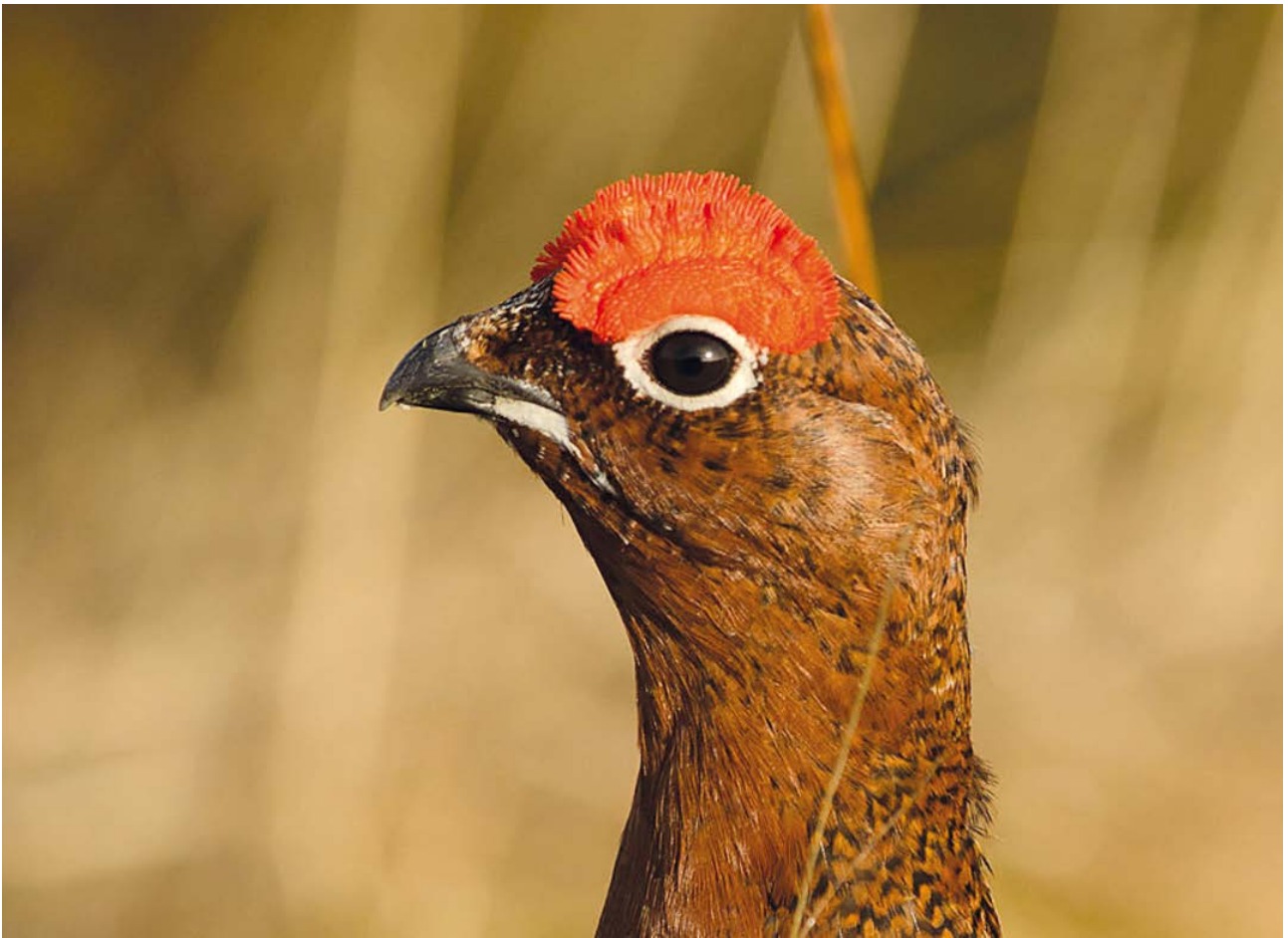
Restarting grouse moor management resulted in an initially modest grouse population increase, but this was not sustained throughout the study period⁹.

The board decided in October 2015 that no further predator control, grouse disease control or active habitat management should be attempted after February 2016 when a) harvesting had not been possible in 2013 or 2014, which were years of good weather and low fox and crow abundance⁴, b) population models in 2015 showed that with average productivity and survival rates there was no chance to reach grouse density needed to achieve the chosen grouse shooting target and c) it was clear that the majority of dead grouse found were associated with signs of predation or scavenging by raptors^{9,10,11} which could not be legally managed.

At this time there seemed no likelihood of a cost-effective solution within the project timeframe, or public policy support for further trials that would allow the partners to collectively test adaptive management measures that might address the apparent challenge of losses to protected predators.

Opposite Top: Red grouse benefitted from moorland management. © Bryan Benn

Opposite Bottom: Diversionary feeding took place throughout the project. © Pete Moore



Objectives and Progress

This section gives an assessment of:

- The evaluation criteria set for the project.
- Progress made by 2014 (the mid-project review point) against the targets³.
- The project progress expected in 2014 to the end of the project (October 2017)³.
- An assessment of actual outcomes at the end of the project (October 2017 unless otherwise stated).

We have used the standard 'traffic-light' system to provide a clear visual on progress and the end of project projection:

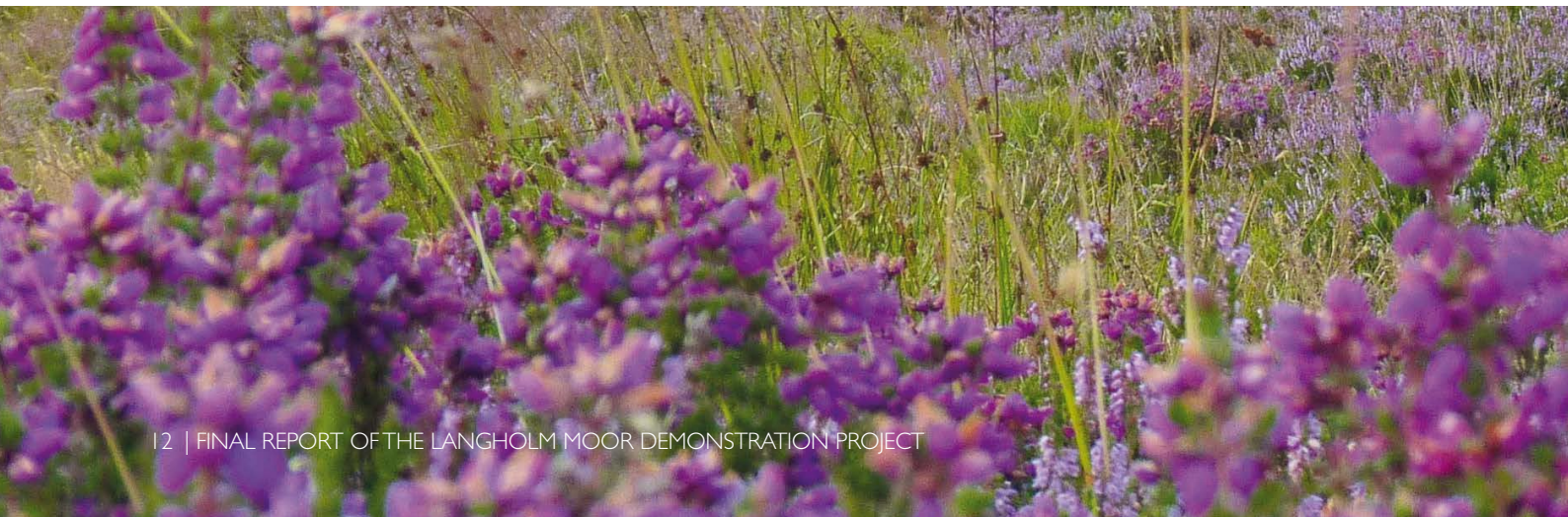
Green = on target/project target already met.

Amber = not on target but management intervention expected to bring it back on track.

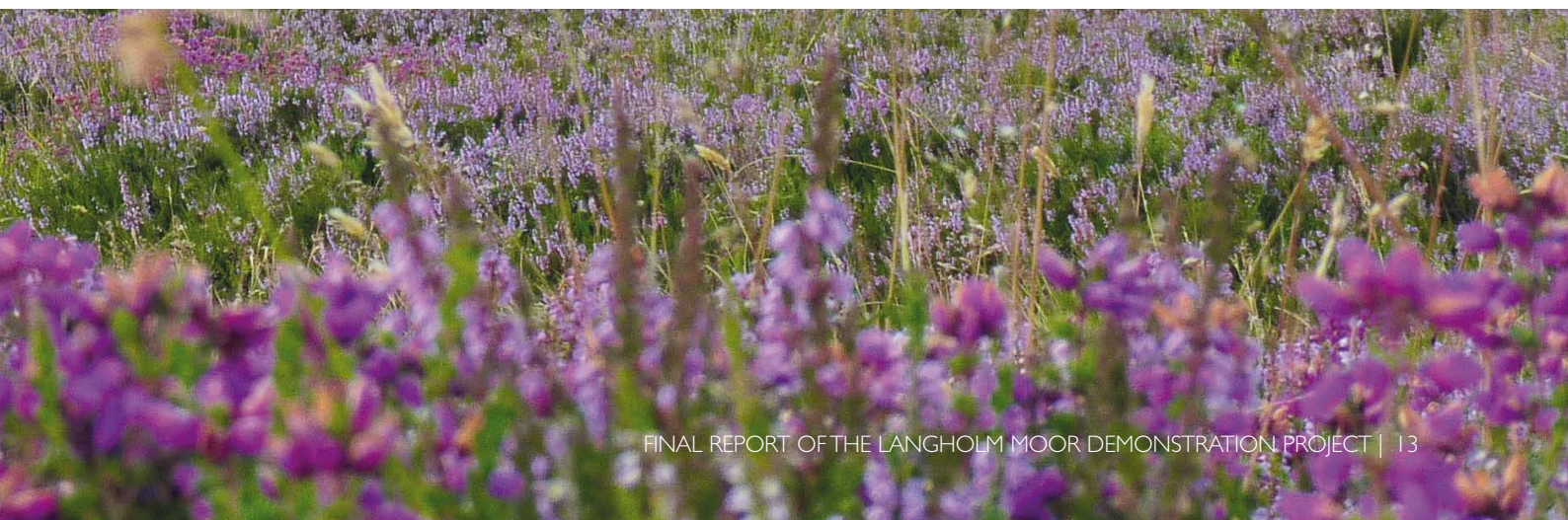
Red = not on target and unlikely to be influenced directly by project actions.

	PROGRESS: 2008 – 2014	
EVALUATION CRITERIA	STATUS	NOTES
Compatibility between management for raptor and red grouse interests	●	Not achieved with the available policy management tools; raptor conservation favourable, but predation pressure resulted in insufficient grouse to drive.
Habitat improvement	●	Heather area and condition good.
Red grouse	●	From a low starting abundance, grouse numbers had not recovered enough for driven shooting by autumn 2014.
Raptors	●	Project targets were met or exceeded in some years.
Other wildlife – waders and passerines	●	Targets were not met for waders; meadows pipits were on target in 2014.
Stakeholder engagement and influence	●	35 on-site visits. 20 off-site events. 9 other activities. Reached at least 1,350 people.

Bottom: Heather cover recovered during the project.
© Adam Smith



PROJECTED PROGRESS: 2015 – 2017		OUTCOME: OCTOBER 2017	
STATUS	NOTES	STATUS	NOTES
→ ● / ● (with adaptive management)	Further adaptive management ²³ was felt needed to benefit both raptor conservation and grouse management.	●	Traditional and novel moorland management was beneficial to both ground-nesting raptors and grouse ^{4,8,9} . Full compatibility was not possible because predation meant the grouse population could not sustain driven shooting ^{10,11} . Management was stopped with possible loss of raptor conservation status. Adaptive management, identified in 2015 as needed to reduce predation pressure ³ , was not undertaken.
→ ● ●	Habitat should have further improved.	● ●	Project management improved cover of the designated site's key heather habitats ^{7,8} .
→ ● (with adaptive management)	Further adaptive management was felt needed to reach sustainable driven densities.	● / ●	Post-breeding densities in 2017 were a third of the peak density in 2014, similar to the start of the project in 2008. Legal gamekeeping reduced predation pressure and maintained grouse productivity ^{9,10} . Site habitat was not the key limit to grouse populations ^{8,7} . Predation pressure limited grouse survival; 79-97% of adult grouse mortality was linked to consumption by raptors ⁹ . Predation effects varied with predator and other prey abundance ^{10,11,13,15} .
→ ●	Raptors were expected to remain in good conservation status.	● / ●	From 2008-2017, the breeding abundance of peregrine, buzzard and raven were stable, whereas numbers of hen harrier and merlin increased ⁵ . Hen harrier breeding abundance peaked in 2014 and thereafter declined ⁴ . There was evidence of loss of hen harrier and merlin conservation status without gamekeeping ^{4,5} . Buzzard hunting numbers were influenced by prey availability ^{13,14,15} .
→ ●	Wader numbers were expected to further improve.	● / ●	Curlew, golden plover and snipe increased in abundance but were only approaching target levels; lapwing numbers did not change ⁶ . Gamekeeping from 2008 to February 2016 may not have been long enough for full recovery ⁷ . Meadow pipit numbers remained on target at the end of the project.
→ ●	Further improvement in understanding of practicable and acceptable options to resolving current management concerns were sought.	● / ●	The last Ministerial visit was 2015. Visits continued to the end of project and the last formal visit was summer 2018. The project informed debate over the possible outcomes, necessary management and investment drivers for managed moorland. Extensive coverage in sporting and conservation media suggests an ongoing division of opinion on these issues.



Partnership Board Report

Heather-dominated moorland is an EU priority habitat and around 75% of it is found in the UK. When actively managed heather moors are considered by some people as a unique part of the social, cultural and economic activity of the British Isles and are an increasingly important refuge for some plants and wildlife.^{18,21}

Yet managed moorlands face many challenges, among them changing attitudes to game shooting; economic pressures on upland farming; public policy drivers for further afforestation; community empowerment; expanding numbers and species of predators; and climate change.

1. Assumptions:

The project objectives assumed public benefits from having active management on heather dominated moorlands and we set out to achieve this in a manner that would reflect how it could be done at as low a cost to the public purse as possible on this site. We wanted to recreate a financially viable grouse moor and in doing so improve the upland habitat and bird assemblage on Langholm moor; meeting the SPA target for hen harrier numbers; and demonstrate what was needed to achieve and sustain such a change³. We believe these assumptions were and remain relevant.

2. Legacy:

As a partnership of bodies with a range of roles in, and views of, moorland management we were uniquely placed to gather trusted knowledge and demonstrate management effects on an impartial basis. This work has helped partners and policymakers develop legislation such as the Wildlife & Natural Environment (Scotland) Act 2011, and has shaped views on adaptive management of predation²³, muirburn, heather cutting, and designated site management. Many of these issues are being considered by ongoing Scottish Government reviews of moorland management.

Langholm remains a vital reference point in the debate about “*what is a sustainable driven grouse moor?*” Some partners have continued monitoring after the project at their own expense to track further changes and some results are published on the project’s website (www.langholmproject.com) alongside this report.

3. Challenges:

The partnership achieved much, as identified in the **Objectives and Progress** section. There were differences of view from within the partnership which reflected some of the wider debate on moorland issues. We recognise that a lack of consensus at critical junctures probably impeded further action on management approaches to the raptor predation and habitat issues we had identified by 2014³.

3.1. Shooting bag:

A key deliverable, because it defined whether the management that benefited habitat and harriers would continue, was that “*The number of red grouse harvested (shot) would be sufficient to ensure the moor reaches a financially viable state.*”³ It was felt that five gamekeepers were needed to achieve the level of habitat and predator control required to meet



The project informed many visitors including Scottish Government ministers about moorland management. © Adam Smith/LMDP

the project deliverables and yield any sustainable shooting. It was initially determined that the market incentive required to fund this would be 2000 brace shot in a season. During the project this bag was revised downwards to 1000 brace, reflecting that there was less heather habitat than expected when the project started, and to set a more achievable target within the project period.

We do not have any evidence that the contemporary market for sporting lets would have accepted an even lower bag size for this level of management investment. Fewer gamekeepers would have reduced the cashflow cost of around £215,000 a year. However as the project results indicate, it seems unlikely that fewer gamekeepers would have been either effective in producing the conditions for sustainable grouse shooting^{4,9} or have a positive impact on habitat^{7,8} and predators to the benefit of harriers^{4,5,10} and wading birds⁶.

3.2. Timescale:

Toward the end of the project there was a difference of opinion on whether to continue to manage the moor in the hope of a change in outcomes. If funding could have been secured, our analyses so far suggest that further predator control and a longer period of grazing exclusion would have resulted in more heather habitat⁸ and possibly higher wading bird numbers⁶. However, the evidence available suggests the outcome for red grouse would only change if their breeding success and survival could further improve^{4,8,10,11}. In 2013-2014 conditions existed for grouse to produce a harvestable surplus but this did not approach 1000 brace.

3.3. Knowledge:

The evidence we gathered in three key areas remains open to further interpretation: a) the impact of raptor predation versus scavenging; b) the proportional contribution of individual species to overall raptor predation pressure; and c) evidence for the importance of other factors (habitat, weather). While the papers published represent the best available evidence, we feel that trial management could tell us more.

4. Challenges beyond the project:

This report is being published at a time critical for moorland policy, when Scotland and the UK as a whole are facing many questions about land use.

- There are a number of options for our hills, of which heather dominated moorland, supporting a particular range of natural capital is one. Managing for these moorlands, which have been described as '[Scotland's] national signature landscape' is desirable because as Langholm moor suggests, some high conservation status species and habitats can lose out if grouse shooting and moorland management are lost, with social and economic consequences.
- As this project indicates there are choices to make about how to fund such management. The changes in subsidy for land management activity, in the event of Brexit, are unclear at this stage. A case for support will need to be made for moorland management derived 'public goods' such as biodiversity and mitigation of climate change. While moorlands may benefit from some public subsidy, full public financial support for moorlands cannot necessarily be relied upon. Given the right conditions private investment is willing to take on some of this burden; but this project's outcomes would not have incentivised a third party to continue to manage the moor. Choices therefore lie in balancing incentive (shooting intensity which drives management), cost (recovery of costs for supply of public goods) and regulation (the legal framework for wildlife management can and does change based upon knowledge of numbers and impacts).
- Driven grouse moors should be encouraged to demonstrate the conservation of heather habitats and raptors. On this moor recovering

shooting to the chosen economically sustainable levels was not possible given the level of (in some cases only controllable under specific licence) predation pressure. Lowering predation pressure (perhaps because predator abundance is lower and new techniques such as diversionary feeding or brood management, which some partners support, are available to use) and supporting grouse densities and productivity opens up options. Moors may be able to drive grouse and sustain more abundant raptor populations, though with some loss of driven moor capacity/consistency. However, there may be resistance by some land managers to adopting such new techniques without better evidence these can be an integrated component of grouse moor management that contributes to commercially sustainable shooting¹⁰.

- Public policy could help reduce pressures on moorland management in other ways. More work is needed to establish the benefits, perhaps using data from Langholm, but land use policy in the uplands could maintain connectivity of large extents of quality habitats at a landscape scale, protecting open ground habitats from commercial afforestation and other threats.

If there are public benefits to maintaining grouse moor management, the work at Langholm has generated important evidence on ways forward. The current grouse moor management toolbox including predator control, muirburn and medicated grit, where used, must be used in line with best practice. New legal predation management options, beyond diversionary feeding, may be needed to allow grouse recovery from low densities. Finally driven grouse shooting may have to charge more for fewer brace of grouse shot to maintain management that is both effective and socially acceptable.

5. Conclusion:

This project demonstrated that for Langholm moor it was not straightforward to sustain driven grouse moor management and the conservation benefits it can support. As a result, some of the choices that face both Langholm and some of the UK's other managed moors are now better understood.

Opposite Top: The Langholm Initiative's Moorland Education Project and 'Making the Most of Moorlands' project published online information for local community use. © Cat Barlow

Opposite Bottom: Board Directors consulted each year on shooting prospects. © Adam Smith/LMDP



Paper Summaries

- The agreed, detailed interpretations of data collected by the project are found in twelve scientific documents produced by the project's research team and collaborators. The conclusions drawn in this report are based on these findings.
- These scientific documents are summarised in this section. There is a standard layout which includes as much original text as possible from the source document. 'Capsule' summaries are either taken from the source or if newly written have been approved by the Project's 'Science Contact Group'[†].
- All the detailed findings were assessed by the Project's 'Science Contact Group' before submission to scientific journals for further scrutiny, a process known as peer-review, and then publication as papers.
- Nine of the twelve submitted documents have been published. Three papers (*) are submitted for peer-review; we have included the project scientists' agreed summaries of these papers. The full reference is given where the paper has been published.
- The papers are ordered to help explain the project's outcomes: What was the effect of management on grouse, raptors and waders? Where was the population 'pinchpoint' for grouse? Was this a habitat effect? What role did predation by raptors play? What other factors may have been important and interesting.
- The papers are:
 - Long-term trends in abundance and breeding success of red grouse and hen harriers in relation to changing management of a Scottish grouse moor.
 - Long-term changes in the abundance and breeding success of raptors and raven in periods of varying management of a Scottish grouse moor.*
 - Responses of breeding waders to restoration of grouse management on a moor in South-West Scotland.
 - Changes in sheep grazing dictate patterns of heather loss and subsequent recovery, but not those of red grouse, on a Scottish moor.*
 - Population responses of red grouse to expansion of heather cover on a Scottish grouse moor.
 - Survival of chicks and adults explains variation in population growth in a recovering red grouse population.
 - Diversionary feeding and nestling diet of hen harriers.
 - Measures of predator diet alone may underestimate the collective impact on prey: common buzzard predation of economically important red grouse.
 - Assessing prey provisioned to common buzzard chicks: a comparison of methods.
 - Winter diet of common buzzards on a Scottish grouse moor.
 - Numerical and functional responses of common buzzards on a Scottish grouse moor.
 - Do fluctuations in field vole abundance indirectly influence red grouse density or demographic rates via shared predator species?*

Links to the published papers are given below, and may be found at:
www.langholmproject.com

[†] The Project's Science Contact Group comprised staff of the Royal Society for the Protection of Birds, Game & Wildlife Conservation Trust, Scottish Natural Heritage and Natural England.

Long-term trends in abundance and breeding success of red grouse and hen harriers in relation to changing management of a Scottish grouse moor

Capsule:

- Data on populations of red grouse, harriers and other predators were collected at Langholm Moor between 1992-2015.
- During the study period the moor saw the ending and subsequent restarting of grouse moor management.
- Overall grouse moor management had a positive effect on abundance and breeding success of grouse and harriers.

Aims:

To consider how ending and subsequently restarting moor management for red grouse, which involved heather management and legal control of generalist predators, affected the abundance and breeding success of red grouse and hen harrier, as well as the abundance of their perceived key predators; red fox and carrion crow.

Methods:

We monitored red grouse, hen harrier, fox and carrion crow during three periods. First between 1992 and 1999, whilst Langholm Moor was managed as a grouse moor. Second between 2000 to 2007, when the moor was not managed for grouse. Third from 2008 to 2015 when grouse moor management was reinstated with the aim of restoring driven grouse shooting.

Results:

Grouse moor management had a positive effect on the abundance and breeding success of grouse and harriers, which were two- to three-fold higher when fox indices and crow abundance were reduced by 50–70%. Fox indices were negatively correlated with red grouse density and harrier breeding success, whereas crows were negatively correlated with grouse breeding success.

Conclusion:

Large areas of heather moorland in the British uplands are managed for shooting red grouse. However, there has been a long-standing conflict between grouse moor management and the conservation of raptors, particularly the hen harrier *Circus cyaneus*. This study confirms that both grouse and harriers can benefit from grouse moor management, if harriers are not persecuted. However, restoration of grouse moor management, in combination with diversionary feeding of harriers, has not yet resulted in a sufficiently increased grouse density to allow driven shooting on Langholm Moor; and thus the management to be considered economically viable.



Trapping reduced crow abundance. © SNH

This summary is based on:

Ludwig S., Roos S., Bubb D. & Baines D. (2017) Long-term trends in abundance and breeding success of red grouse and hen harriers in relation to changing management of a Scottish grouse moor. *Wildlife Biology*.

Online - <https://doi.org/10.2981/wlb.00246>

Long-term changes in the abundance and breeding success of raptors and raven in periods of varying management of a Scottish grouse moor

Capsule:

- The numbers of raptors and ravens and how many young they produced was assessed between 1992 and 2018 on Langholm moor.
- Controlling foxes helped ground-nesting raptors rear more young and population size increased, but the same management did not appear to affect tree and crag nesting species.
- Legal predator control can benefit ground-nesting raptors, but ongoing persecution affects the conservation status of some species.

Aims:

To quantify whether management of heather moorland for driven red grouse shooting in the British uplands can benefit raptors by reducing predation risk, especially when breeding, and increasing food availability.

Methods:

We assessed changes in abundance and breeding success of raptors and raven over 27 years on Langholm moor in relation to whether or not the moor was managed by gamekeepers.

Results:

Ground-nesting raptors, hen harrier and merlin, increased during periods of grouse moor management and had a higher proportion of successful nesting attempts. Predation, mainly by foxes when their numbers were not controlled, was the main cause of breeding failure. In contrast, grouse moor management did not influence either abundance or breeding success of tree- and crag-nesting species, i.e. peregrine, buzzard and raven. Buzzard sightings increased during the study, in line with their national recovery, whereas peregrine and raven showed little change in abundance.

Conclusion:

The results of our study highlight that legal predator control can benefit ground-nesting raptors, but on a national scale these benefits to hen harriers are outweighed by illegal control, caused by fears that their consumption of grouse can undermine the economics of grouse moor management.



Hen harriers often had five chicks per nest.
© Dr Sonja Ludwig

This summary is based on a submitted paper:

Ludwig, S, Roos, S., Rollie, C. & Baines, D. Long-term changes in the abundance and breeding success of raptors and raven in periods of varying management of a Scottish grouse moor:

Responses of breeding waders to restoration of grouse management on a moor in South-West Scotland

Capsule:

- Wading bird abundance was recorded over 10 years at Langholm.
- Restoring predator control reversed declines of curlew and golden plover, but not lapwing; snipe continued to increase.
- The local increases in abundance were achieved in contrast to regional and national declines.

Aims:

To assess whether the restoration of grouse moor management, which includes control of predators and heather habitat management, would halt and reverse declines in breeding wader abundance.

Methods:

Changes in the abundance of four upland-breeding wader species were monitored following restoration of grouse moor management at Langholm Moor in SW Scotland from 2008 to 2017. Here, curlew, golden plover and lapwing had previously declined when management ceased, whereas snipe had increased.

Results:

During the 10-year study period, curlew numbers increased on average by 10% per annum, golden plover numbers by 16% and snipe numbers by 21%, whereas lapwing numbers did not change. These local trends contrast with national and regional trends over the same period, which all showed declines of all these species. However, the population trends for curlew and snipe did not differ in relation to habitat management for red grouse, suggesting that population increases were primarily associated with predator control across the whole study area.

Conclusion:

Worldwide, many wader species have recently exhibited steep declines in range and abundance. Low productivity, often associated with predation, is considered a major proximate driver of declines and often reflects underlying land use and habitat change. The results support the hypothesis that restoring predator control as part of grouse moor management can reverse declines of some wader species. At Langholm, full recovery to levels observed prior to management cessation may have been constrained by delayed recruitment within a time-restricted study period in combination with low initial numbers, availability and isolation of suitable habitat, and incomplete predator removal.



Lapwing and other waders benefited from game keeping. © Adam Smith

This summary is based on:

Ludwig, S.C., Roos, S. & Baines, D. 2019. Responses of breeding waders to restoration of grouse management on a moor in South-West Scotland. *Journal of Ornithology* 160: 789–797.

Online - <https://doi.org/10.1007/s10336-019-01667-6>

Changes in sheep grazing dictate patterns of heather loss and subsequent recovery, but not those of red grouse, on a Scottish moor

Capsule:

- Afforestation and intensification of sheep grazing in the British uplands have led to widespread declines in heather moorland, a globally rare habitat.
- Between 1948 and 2009, 73% of heather dominated habitat was lost on Langholm moor; although a large area of dominant heather was retained at higher altitude.
- Heather loss was reversed where grazing pressure was reduced in 2011 and game keeping on the remaining heather increased grouse numbers, but predation prevented the production of enough grouse for driven shooting.

Aims:

To examine the consequences of changes in the intensities of both sheep grazing and management for grouse on Langholm Moor for heather cover and red grouse abundance.

Methods:

We quantified changes in heather cover over 70 years in relation to changes in sheep grazing on Langholm Moor; managed for red grouse shooting and sheep farming, and related this to changes in red grouse abundance (estimated from shooting bags and counts). For comparison, we quantified land cover changes in the wider landscape around Langholm Moor.

Results:

Between 1948 and 2009, when grazed heavily by sheep, heather-dominated vegetation declined by 73%. However, a large area of contiguous heather moorland was retained, especially at higher altitude. Numbers of grouse shot on Langholm Moor declined between 1951 and 1992 where heather was largely lost. They remained high where 37-65% of dominant heather cover was retained, but then declined between 1992 and 1996 following increased predation by raptors, leading to the cessation of shooting. Subsequently, grouse densities fluctuated in relation to periodic management by gamekeepers (1992-1999 and 2008-2016). Large-scale sheep reductions from 2011 increased heather-dominated habitat by 26% by 2015, although it still covered only 33% of its extent in 1948. However, predation, largely associated with raptor signs, prevented sustained increases in grouse densities to a level considered adequate for 'driven' shooting.



Heavy grazing by sheep can result in heather loss.

Conclusion:

Grouse shooting provides an economic incentive to help maintain and restore heather moorland. On Langholm Moor, however, afforestation in the surrounding landscape and isolation from other heather moors may have led to a grouse population less well buffered against growing predation pressure, especially outside kept periods. As grouse shooting could not be restored, the future management of the moor remains uncertain.

This summary is based on a submitted paper:

Changes in sheep grazing explain patterns of heather *Calluna vulgaris* loss and subsequent recovery, but not those of red grouse *Lagopus lagopus scotica*, on a Scottish moor: Ludwig SC, Aebischer NJ, Richardson M, Roos S, Thompson DBA, Wilson JD & Baines D.

Population responses of red grouse to expansion of heather cover on a Scottish grouse moor

Capsule:

- A reduction in sheep grazing pressure was associated with increased heather cover between 2008 and 2016.
- Grouse densities were higher in areas with more heather, but they did not breed or survive better.
- Increasing heather cover can help support more red grouse but only if predation and disease pressures are first reduced.

Aims:

To determine whether restoring heather habitat at Langholm, where heather was previously in decline, improve red grouse density, productivity and survival.

Methods:

Spatial and temporal relationships between red grouse demographic rates, estimated from counts, and habitat variables measured from ground and aerial vegetation surveys were analysed. The relationships between survival of radio-tagged grouse and habitat variables measured in their individual home range were also assessed.

Results:

Reductions in sheep grazing and other heather restoration measures (i.e. burning and cutting, and in some areas re-seeding of heather following herbicide treatment to reduce grass-dominance) increased total heather cover by 10% and the area of heather-dominated vegetation by 30% within six years. Pre-breeding, and for aerial surveys also post-breeding, densities of red grouse were highest in areas with more heather cover (range: 0-92%), and pre-breeding densities increased more where heather recovery was greatest. However, we found no relationship between heather cover and red grouse productivity or survival rates, the latter also when rates were estimated from radio-tagged individuals. Changes in heather cover were not associated with changes in post-breeding densities or survival of red grouse, although they were positively related to change in productivity for aerial surveys.

Conclusion:

Loss of heather dominated moorland in Britain has been associated with long-term declines in red grouse. This is the first study examining red grouse responses in relation to changes in heather cover within the same site, in contrast to previous between-moor comparisons, where other factors may have contributed to variation in red grouse demography. Overall, management for red grouse had a larger effect on density and productivity than reductions in sheep grazing which led to increases in heather cover. The results suggest that, in the long term, heather restoration has the potential to increase red grouse carrying capacity, but realizing this potential first requires improving red grouse demographic rates.



Cutting, burning and managing grazing led to heather habitat recovery during the project.
© Lorne Gill/SNH

This summary is based on:

Ludwig S., Aebischer N., Bubbs D., Richardson, M., Roos S., Wilson J. & Baines D. (2018) Population responses of Red Grouse *Lagopus lagopus scotica* to expansion of Heather *Calluna vulgaris* cover on a Scottish grouse moor. *Avian Conservation & Ecology* 13:14
Online - <https://doi.org/10.5751/ace-01306-130214>

Survival of chicks and adults explains variation in population growth in a recovering red grouse population

Capsule:

- Understanding which life-stages best explain population change can help focus management for a species.
- Survival of adults and chicks were the key life stages for red grouse at Langholm with low survival limiting population recovery.
- Mortality associated with raptor signs was the most important factor determining adult survival and was closely linked to low rates of chick survival.

Aims:

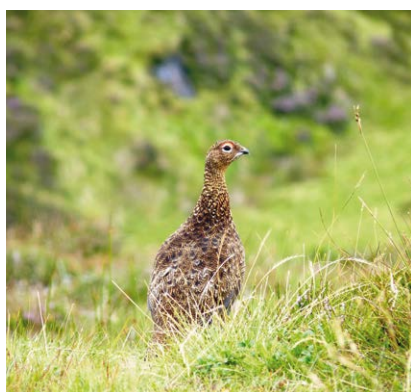
Examining which life stages, from clutch to adult, contributed most to population growth in a recovering red grouse population following restoration of management aimed at resuming economically viable harvesting.

Methods:

Density and demographic parameters such as survival and breeding success were derived from biannual grouse counts and from radio-tagged grouse. These data were analysed using standard demographic approaches. We also analysed life-specific causes of mortality.

Results:

When estimates were based on grouse counts, a combination of adult summer and winter survival contributed most to population change. When based on the lifespan of radio-tagged birds, deemed more reliable because of independence between parameters and years, adult summer survival and chick survival contributed most to population change. The contributions to population growth of clutch size, nesting success (i.e. the proportion of nests with at least one egg hatching) and hatching success (proportion of eggs hatching in successful nests) were negligible. Analysis of grouse carcasses found that 82% were associated with signs of predation or scavenging by raptors.



Survival and breeding success of hen grouse was too low to allow driven shooting. © Adam Smith

Conclusion:

Understanding demographic mechanisms is key to managing animal populations, both in conservation and game management. At Langholm, the survival rate of adults and chicks contributed most to annual population change in grouse and reduced the rate of population recovery. Rates of juvenile production exceeded those of adult mortality, allowing modest population growth, but insufficient to resume economically viable harvesting.

This summary is based on:

Ludwig S., Aebischer N., Bubbs D., Roos S., & Baines D. (2018) Survival of chicks and adults explains variation in population growth in a recovering red grouse population. *Wildlife Biology*.

Online - <https://doi.org/10.2981/wlb.00430>

Diversionary feeding and nestling diet of hen harriers

Capsule:

- Diversionary feeding reduced hen harrier nestlings' natural food intake by half.
- Red grouse chicks constituted 0–4% of all nestling food items.
- Annually, this reduced annual grouse chick production by 0–6%.

Aims:

To quantify proportions of diversionary and natural food (including grouse) delivered to hen harrier nestlings in relation to brood size, male status and natural prey abundance.

Methods:

Diversionary food was provided to 25 hen harrier broods (2008–15). The diet of 15 broods was assessed using observations from hides, nest cameras and regurgitated pellet analysis. Variation in nestling diet was analysed using compositional analysis.

Results:

Hen harriers took 76% of diversionary food provided. Depending on assessment method, average nestling diet was 44–53% diversionary food, 39–55% natural prey (including 24–45% passerines, 4–15% small mammals, 0–4% grouse chicks) and 0–9% unknown items. The amount of diversionary food consumed was not influenced by male status, brood size or natural prey abundance. The number of red grouse chicks delivered annually was 34–100% lower than expected under unfed conditions, however; the confidence intervals associated with these estimates were large.

Conclusion:

Diversionary food influenced hen harrier nestling diet and reduced the number of red grouse chicks taken relative to modelled predictions. Such feeding may help reduce conflict between hen harrier conservation and red grouse shooting, but only if overall grouse productivity is thereby maintained or increased.



Diversionary feeding of hen harriers using day old chicks. © LMDP

This summary is based on:

Ludwig S., McCluskie A., Keane P., Barlow C., Francksen R., Bubbs D., Roos S., Aebischer N. & Baines D. (2018) Diversionary feeding and nestling diet of Hen Harriers *Circus cyaneus*. Bird Study 65: 431–443

Online - <https://doi.org/10.1080/00063657.2018.1519524>

Measures of predator diet alone may underestimate the collective impact on prey: common buzzard predation of economically important red grouse

Capsule:

- The potential impact of buzzards on grouse between 2011 and 2015 was studied using estimates of buzzard diet and abundance in bioenergetics models.
- The number of grouse eaten by an individual buzzard was low, but the total consumption across all buzzards present could be considerable.
- It is possible that grouse consumption by buzzards contributed to limiting grouse recovery at Langholm, but only if buzzards killed all grouse that they consumed.

Aims:

To estimate the potential impact of buzzards on red grouse on Langholm moor:

Methods:

Bioenergetics models combined measures of buzzard abundance from field surveys with diet composition, assessed by using cameras at nests, prey remains and pellet analysis, to estimate consumption of grouse (adults and chicks).

Results:

Whilst grouse consumption by individual buzzards was low, total consumption could be considerable given an estimated 55-73 buzzards were present on the 115 km² study site year-round. Averaging across diet assessment methods, consumption models estimated that during each of three breeding seasons (April-July 2011-2013), buzzards consumed 73-141 adult grouse and 77-185 chicks (depending on year). This represented 5-11% of adult grouse present in April (22-67% of estimated adult mortality) and 2-5% of chicks that hatched (3-9% of estimated chick mortality). During two non-breeding seasons (August-March), consumption models using pellet analysis estimated that buzzards ate a total of 242-400 grouse, equivalent to 7-11% of those present at the start of August and 14-33% of estimated grouse mortality during the non-breeding season.



Red grouse were prey to buzzards. © Adam Smith

Conclusion:

Human-wildlife conflicts often centre on economic loss caused by wildlife. Yet despite being a major issue for land-managers, estimating total prey losses to predation can be difficult. Estimating impacts of protected wildlife on economically important prey can also help management decisions to be evidence-led. The recovery in population and range of common buzzards in Britain has brought them into conflict with some gamebird interests. However, the magnitude of any impact is poorly understood. This study suggests that buzzard consumption of grouse has the potential to lead to non-trivial economic loss to grouse managers, but only if buzzards preyed on the grouse they ate, and if grouse mortality is additive to other causes.

This summary is based on:

Francksen R., Aebischer, N., Ludwig, S., Baines D. & Whittingham M. Measures of predator diet alone may underestimate the collective impact on prey: common buzzard *Buteo buteo* predation of economically important red grouse *Lagopus lagopus scotica*. PlosOne 14(8): e0221404
Online - <https://doi.org/10.1371/journal.pone.0221404>

Assessing prey provisioned to common buzzard chicks: a comparison of methods

Capsule:

- Methods of assessing raptor diet carry significant inherent biases which can vary over time.
- Under-estimation of small mammals and over estimation of birds requires particular attention.
- Combining methods may help to reduce some of these biases.

Aims:

To compare methods of assessing common buzzard *Buteo buteo* diet composition and assess how any differences vary between years.

Methods:

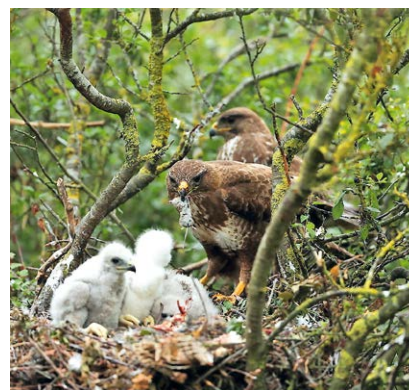
Diet was assessed at 32 common buzzard nests at Langholm, managed for red grouse, over three years. Data obtained from nest cameras were compared with data from prey remains and regurgitated pellets.

Results:

Diet composition differed between methods in all years. Methodological differences varied between years in relation to an almost twelve-fold change in field vole abundance, a key prey of common buzzards, while abundances of alternative prey changed little. Small mammals were underestimated by prey remains in all three years, while herpetofauna were underestimated by prey remains and pellets in two years. Large birds were overestimated by prey remains, significantly so in one year. Pellets overestimated invertebrates in all years. By combining prey remains and pellets, significant yearly variations in biases were eliminated, although the combined measure overestimated large birds and invertebrates.

Conclusion:

Our results suggest that future studies should consider not only how chosen methods may affect results, but also how effects can differ between years.



Small mammals were a key food for buzzards.
© Andrew Everritt

This summary is based on:

Francksen R., Whittingham M. & Baines D. (2016) Assessing prey provisioned to common buzzard *Buteo buteo* chicks: a comparison of methods. *Bird Study* 63: 303-310.

Online - <http://dx.doi.org/10.1080/00063657.2016.1183111>

Winter diet of common buzzards on a Scottish grouse moor

Capsule:

- Common buzzards ate mostly small mammals during winter periods.
- Grouse were a minor prey item.
- Fewer grouse were eaten when grouse abundance declines.

Aims:

To assess winter diet of common buzzards from pellets collected at roost sites on and around Langholm moor; and to explore temporal, spatial and age-related variation in diet composition.

Methods:

Forty-four winter roost sites were located during two winters using a combination of observations from vantage points and individual common buzzards equipped with either radio or satellite transmitters. Pellets were collected between October and March each winter and analysed to assess dietary composition.

Results:

Small mammals were the main prey in both years, comprising 60-67% of items and occurring in 88-92% of pellets. Diet varied between years, with more rabbits and hares and birds (passerines, corvids and pigeons) but fewer red grouse eaten when grouse abundance declined. Grouse formed 1.1% and 0.6% of prey items, and occurred in 3% and 2% of pellets from each winter, respectively.

Conclusion:

Common Buzzards rely on small mammal prey during winter. When available, red grouse are a minor dietary component, the amount of which reflects their abundance in the environment. The opportunism of common buzzards can result in temporal variation in winter diet.



Some Common Buzzards were fitted with GPS transmitters to track their movements. © LMDP

This summary is based on:

Francksen R., Whittingham M., Ludwig S. & Baines D. (2016) Winter diet of common buzzards *Buteo buteo* on a Scottish grouse moor: Bird Study 63: 525-532.

Online - <http://dx.doi.org/10.1080/00063657.2016.1238868>

Numerical and functional responses of common buzzards on a Scottish grouse moor

Capsule:

- Buzzards switch between prey species in response to changing prey abundance.
- In 2011 field voles were common on the moor, encouraging buzzards to hunt this habitat, thus incidentally finding and predating grouse.
- In 2012 and 2013 fewer field voles on the moor led buzzards to hunt away from the moor on the hill edge, reducing predation on grouse.

Aims:

To investigate the demographic and aggregative numerical and functional responses of Common Buzzards in relation to variations in prey abundance on Langholm moor.

Methods:

Buzzard, red grouse and vole abundance were determined over three consecutive breeding and non-breeding seasons. Predation of red grouse by buzzards was predicted to increase when abundance of their preferred field vole prey declined.

Results:

As vole abundance fluctuated, buzzards responded functionally by eating voles in relation to their abundance but did not respond demographically in terms of either breeding success or density. During a vole crash year, Buzzards selected a wider range of prey typical of enclosed farmland habitats found on the moorland edge, but fewer grouse from the heather moorland. During a vole peak year, prey remains suggested a linear relationship between grouse density and the number of grouse eaten (a Type I functional response), which was not evident in either intermediate or vole crash years. Buzzard foraging intensity varied between years as vole abundance fluctuated, and foraging intensity declined with increasing heather cover.

Conclusion:

Predators will often respond to reductions in preferred prey by switching to alternative prey resources. However, this may not apply to all alternative prey groups in patchy landscapes. Our findings did not support the prediction that predation of red grouse would increase when vole abundance was low. Instead, they suggest that buzzards preyed on grouse incidentally while hunting for voles, which may increase when vole abundances are high through promoting foraging in heather moorland habitats where grouse are more numerous. Our results suggest that declines in their main prey may not result in increased predation of all alternative prey groups when predators inhabit patchy landscapes. We suggest that when investigating predator diet and impacts on prey, knowledge of all resources and habitats that are available to predators is important.



Buzzard breeding success was not directly linked to vole abundance. © Andrew Everitt

This summary is based on:

Francksen R., Whittingham M., Ludwig S., Roos S. & Baines D. (2017) Numerical and functional responses of common buzzards *Buteo buteo* on a Scottish grouse moor. *Ibis* 159: 541-553.

Online - <https://doi.org/10.1111/ibi.12471>

Do fluctuations in field vole abundance indirectly influence red grouse density or demographic rates via shared predator species?

Capsule:

- Changes in the abundance of one prey species may indirectly affect other prey species by triggering responses in generalist predators.
- Vole abundance was not associated with grouse densities, adult survival or nesting success but the number of chicks in a brood and the number of female grouse with broods was lower with higher vole abundance.
- This negative interaction between field voles and red grouse chick survival may be at least partly mediated by rodent-hunting raptors such as buzzards and, in periods without management for grouse, foxes.

Aims:

We examine relationships between two prey species that do not compete directly, field voles, a common rodent with cyclically fluctuating populations, and red grouse, a gamebird inhabiting open moorland, during a 26-year study on a moor in south-west Scotland.

Methods:

We tested whether vole abundance was related to grouse density and demographic rates, and to abundance indices of four common predators of both voles and grouse (red fox, weasel, hen harrier and common buzzard), and whether these relationships differ in relation to management for grouse, which includes the culling of foxes and weasels.

Results:

We found no association between vole abundance and grouse densities, adult summer survival or nesting success. However, the ratio of young per adult and the proportion of females with broods in July were negatively associated with field vole abundance. Fox indices were only positively related to vole abundance when their numbers were not controlled, whilst weasel indices showed no relationship with voles. The numbers of breeding hen harriers and buzzards were also not associated with vole abundance, but the number of buzzard sightings was higher when voles were more plentiful.

Conclusion:

Changes in the abundance of one prey species may indirectly affect other prey species by triggering responses in generalist predators. Our results suggest a negative interaction between field voles and red grouse chick survival in a pattern consistent with that generated by apparent competition. Although the underlying mechanisms could not be fully disentangled, this interaction may be at least partly mediated by rodent-hunting raptors such as buzzards and, in periods without management for grouse, foxes.



The numbers of breeding hen harriers and buzzards were also not associated with vole abundance. © Lorne Gill/SNH

This summary is based on a submitted paper:

Ludwig, S, Roos, S & Baines, D. Do fluctuations in field vole abundance indirectly influence red grouse density or demographic rates via shared predator species?

Other project publications:

Clutch abandonment as a result of brood adoption in red grouse

A short note reporting a case where a female red grouse abandoned her own clutch to adopt another grouse brood¹⁶.

Fingland K & Ludwig, S. (2015) British Birds 108: 294

Hen Harrier Conservation Framework

A report on conservation work for the hen harrier completed by Scottish Natural Heritage and partners under the species framework initiative¹⁷.

Thompson, DBA, Roos S, Bubb D, Ludwig SC (2016) Hen Harrier. Version 1.0. Scottish Natural Heritage, Battleby, Perth.



View north east into Langholm Moor from the Malcolm Monument. © GWCT

Stakeholder Engagement and Influence

1. Moorland is a complex cultural landscape and from the outset, the project engaged with the wider society that use moorland. This was important for:
 - 1.1. securing support for the project
 - 1.2. increasing awareness of moorland conservation and management,
 - 1.3. developing an appreciation of the need for solutions to the raptor: red grouse conflict,
 - 1.4. using stakeholder knowledge to identify key obstacles to resolution
 - 1.5. identifying options that could help resolve conflict and promote wider use of these conflict resolution tools.
2. **Key stakeholders** for the project were:
 - 2.1. Moorland managers (grouse moor managers, conservation managers), shooting community and estate managers
 - 2.2. Policy makers (Scotland, England, UK, EU)
 - 2.3. The local community
 - 2.4. Scientists and natural history enthusiasts
3. There was a limited public relations budget which a project PR Group used to undertake:
 - 3.1. Website hosting and management (www.langholmproject.com)
 - 3.2. On-site group visits
 - 3.3. Off-site briefings and presentations
 - 3.4. Member/trade magazine articles
 - 3.5. TV and radio
 - 3.6. Word of mouth
 - 3.7. Collaboration with 'Making the most of Moorlands' project
 - 3.8. Attendance and displays at game fairs, member meetings
4. **Delivery:** The Project gamekeepers, scientists and the project manager carried out the majority of the engagement work. Non-Project staff, including Project partner staff, wanting to disseminate information about the Project discussed their approach with the PR group in advance. GWCT hosted and managed the website for the project.
5. **Messaging:** Visitors received the same key messages:
 - 5.1. The value of all aspects of legal predator control
 - 5.2. Diversionary feeding as an option to mitigate impact on grouse from breeding hen harriers
 - 5.3. The habitat improvement achieved.
6. **Outcomes.**
 - 6.1. By 2016 there had been 56 on-site visits, 30 off-site events and 10 other activities in the past three years including radio, television broadcasts, reaching at least 1,650 people³.
 - 6.2. Project staff attended external events including local Game Fairs and the Scottish Game Fair to provide a one-to-one informal opportunity to discuss specific aspects of the Project.
 - 6.3. The gamekeeping team attended shooting days on other moors to provide informal updates to guns, Estate owners and staff and others; an effective mechanism to disseminate key messages in a credible and personal form.
 - 6.4. The Project has hosted a large number of visits from policy makers: to introduce them to game management in a moorland setting; illustrate the practicalities of potential new legislation. Visitors included the Rural Affairs Committee in 2010 and each Scottish Government Environment Minister in post during the project: Michael Russell MSP, Roseanna Cunningham MSP, Stewart Stevenson MSP, Paul Wheelhouse MSP and Aileen McLeod MSP. The project was visited in July 2018 by the group chaired by Professor Alan Werritty which is undertaking the Grouse Moor Management Review for the Scottish Government.
 - 6.5. The 'Making the Most of Moorlands' initiative used project information as one of its learning tools for the local community in Langholm. The Project Officer undertook a wide range of events including publicising the movements of hen harriers tagged on Langholm moor by Natural England. Over 5,000 local school children have been made aware of the moor; its wildlife and management.
 - 6.6. Scientists and natural history enthusiasts. The Project hosted informal visits from interested scientists and research workers, covering a wide range of moorland management interests. In addition, off-site presentations were made to a range of Scottish natural history groups³.

Financial Statement

1. The Project board's core objective "To establish Langholm Moor as a driven grouse moor [and] to meet the nature conservation objectives for the SPA and SSSI."³ set the framework for what would need to be spent and the scale of income expected to defray these costs.
2. The management that needed funding would maintain hen harrier conservation status, improve the heather habitat, and harvest enough red grouse to ensure the moor reached a financially viable state.
3. It was hoped to show that the red grouse management would both practically and financially deliver the other goals because it was the only activity that had a reasonable chance to be funded independently of state support in the long run.
4. The target number of grouse to shoot was therefore important. Given the low grouse population at the start of the project, an initial target of 1000 brace per annum was set as an interim target. This did not represent an economic break-even; some 3000 brace would be required to achieve that position, higher even than the original market incentive figure of 2000 brace.
5. No grouse moor management had taken place in the previous eight years at Langholm. So instead of an actual shooting tenant taking on the costs and risk, the project was set up to fund the routine management costs (Table I). These costs were index linked over the term of the project.
6. A breakdown of annual management costs are shown in Annexe A, and partner contributions in Annexe B.
7. It was recognised that major capital investment would be required in terms of habitat improvement, livestock removal and installation of new roads.
8. SNH and Buccleuch funded these separately through a combination of private investment, SRDP grant schemes and its SSSI Management Agreement. This additional investment over the ten-year period was approximately £2,300,000.
9. Over the term of the project:
 - 9.1. the total spent on routine moorland management was around £2,250,000.
 - 9.2. the total cost of capital investment was approximately £1,500,000
 - 9.3. An assessment of total monies spent in the local community (20 mile radius) £3,500,000.
10. The costs of employing skilled keepers who could deliver the objectives was considerable, even on unit area managed basis:

10.1 Labour Costs per acre	Total/Per Annum	£76 / £9.50
10.2. Capital Investment per acre	Total/Per Annum	£82 / £8.20

Item	Amount per year
Staff salaries	£110,000
Other staff support costs	£91,700
Equipment	£6,200
Bracken control	£1,830
Heather restoration	£2,000
Herbivore control	£3,000
Management Costs	£15,000
Total	£229,730*

Table I

Summary of moorland management costs for the Project between 2008 and 2016.

Annexe A: Moorland Management Costs

Table 1

Breakdown of the annual costs of elements of LMDP moorland management.

Staff and running costs	Per Gamekeeper £	Total £	Total per year £
WAGES			
1 Head Gamekeeper	30,000	30,000	30,000
4 Beat Gamekeepers	20,000	80,000	80,000
VEHICLES			
5 Pick-up Trucks	14,000	70,000	
5 ATV	5,000	25,000	
	5 year write down	-	19,000
1 Argocat	15,000		
	5 year write down		3,000
Repairs/tax/insurance		11,000	11,000
Fuel pick ups		12,500	
Fuel ATVs		7,500	
			20,000
DOG ALLOWANCE			
5 Gamekeepers	1,400	7,000	7,000
HOUSING			
5 Gamekeepers	5,000	25,000	25,000*
MISCELLANEOUS			
(clothing, disease testing etc)		6,700	6,700
SUB TOTAL			231,700
EQUIPMENT			
Heather burning equipment		5,000	
Butts		5,000	
Equipment:			
5 guns	1,500	7,500	
5 rifles	1,500	7,500	
5 binoculars	800	4,000	
Vermin control		2,000	
SUB TOTAL	31,000		6,200
	5 year write down		
ADDITIONAL COSTS			
Bracken control (material) per year		1,831	1,831
Heather reseeding over 5 years		10,000	2,000
Additional habitat/grazer management per year		3,000	3,000
TOTAL EXPENDITURE			244,731

Annexe B: Partnership Contributions

	Annual Cost	Total cost over 10 years
Moorland management	£244,731	£2,405,630
Monitoring	£75,150	£841,920
Project management and support costs	£15,800	£177,071
Total	£335,681	£3,424,621

Table 1

Total Cost of Key Activities: The three main cost elements of LMDP, and the total cost over 10 years assumes 2.5% annual inflation.

	Annual Cost	Total cost over 10 years
SNH	£86,893	£973,491
Buccleuch	£86,893	£973,491
GWCT	£86,893	£973,421
RSPB	£30,000	£336,096
Natural England	£15,000	£168,052
Total	£305,680	£3,424,621

Table 2

Total Annual Contributions per Partner: The varying contributions per LMDP partner committed to at the beginning of the Project. Total 10 year cost assumes 2.5% annual inflation.

	Annual Cost	Total cost over 10 years
SNH	£61,040	£683,648
Buccleuch	£61,040	£683,648
GWCT	£61,040	£683,648
RSPB	£21,074	£236,029
Natural England	£10,536	£118,657
Total	£214,730	£2,405,630

Table 3

Moorland Management Contributions: The pro rata contributions per LMDP partner committed to at the beginning of the Project for the moorland management element. Total 10 year cost assumes 2.5% annual inflation.

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Appendix 1

Executive Summary: The Langholm Moor Demonstration Project Seven Year Review – December 2014

- 1.1 This document reviews the first seven years (2008 to 2014) of the Langholm Moor Demonstration Project (LMDP – the project). It is a 10 year project designed to show whether and how it is possible to manage the moor in such a way as to produce a combination of good habitat, a population of breeding hen harriers in line with its SPA status, and economically viable driven red grouse shooting, and thereby a demonstration of how to resolve the conflicts between moorland management for raptors and red grouse. It is the only demonstration of this kind in the UK.
- 1.2 Langholm was the principal moor in the Joint Raptor Study (JRS) in the 1990s which quantified the impact that raptors could have on red grouse, and showed that predation by hen harrier populations may reach levels sufficient to render red grouse shooting unviable. There, when shooting became unviable in 1997, the gamekeepers were laid off¹ and habitat and predator management virtually ceased until the keeping re-started as part of the new LMDP in spring 2008. During that period of little or no keeping crow and fox numbers increased, and breeding hen harrier numbers dropped back to pre-JRS (Joint Raptor Study) levels, grouse numbers further declined, breeding wader populations declined to very low numbers and the status of both the SSSI² and SPA³ was found to be unfavourable. The loss of grouse shooting also had a significant negative impact on the local economy. To many observers this represented a 'lose: lose' situation in terms of nature conservation, culture, employment and economic activity.
- 1.3 The LMDP is designed to work towards a potential 'win: win' situation where breeding raptors co-exist with commercial driven grouse shooting. The project is relevant to other moors; the central question is **'can moors with low grouse numbers achieve an economically viable state in Scotland with the available policy and management tools?'**
- 1.4 The project area covers 11,960 hectares (29,553 acres). It includes the Langholm Moor SSSI/SPA, the areas previously managed as grouse beats, and surrounding buffer areas where legal predator control is undertaken to support the management of the grouse beats.
- 1.5 The core objective is **"to establish Langholm Moor as a driven grouse moor [and] to meet the nature conservation objectives for the SPA and SSSI"**. The project has 4 deliverables:
 1. Demonstration of how to resolve conflicts between moorland management for raptors and red grouse;
 2. The hen harrier population would be maintained as a viable component of the SPA;
 3. The heather moorland habitat would be extended and improved beyond its state in 2002;
 4. The number of red grouse harvested (shot) would be sufficient to ensure the moor reaches a financially viable state.
- 1.6 Progress is guided by six evaluation criteria:
 1. Heather moorland habitat
 2. Red grouse numbers
 3. Hen harriers and other raptors (birds of prey)
 4. Other wildlife - passerines, waders and voles
 5. Compatible management for raptors and red grouse – predators and predation
 6. Stakeholder engagement and influence
- 1.7 We have used a standard 'traffic-light' system to provide a clear visual on progress and the end of project projection (see section 5).
 - 1.7.1 Habitat improvements and raptor populations are both rated **green**. The number of nesting hen harriers in 2014 exceeded the Project target. The moor also supports high numbers of buzzards, alongside goshawks, peregrines, merlin and short eared owls. The targets of expanding the area of heather; and improving heather condition have both been met.

¹ Redeployed to other parts of Buccleuch

² Site of Special Scientific Interest

³ Special Protection Area

1.7.2. Red grouse recovery is classified **red**; despite 7 years of keeping grouse numbers have not recovered sufficiently to allow driven shooting (the target is 1,000 brace shot in one year). It is important to remember that grouse numbers are recovering from a low base. The end of project projection is **red/amber** in anticipation of a need to trial further adaptive management options (in addition to the existing successful diversionary feeding of harrier nests) to benefit both raptor conservation and grouse management and achieve the target for grouse shot.

1.7.3. Waders and passerines are rated **amber**. The population targets have not been met for waders, but have been for meadow pipits (in 2014). It is difficult to predict whether the wader targets will be met by the end of the project given the decline in wader numbers nationally during the period of the project, but it is hoped they will respond to habitat improvements.

1.7.4. We have not yet achieved the desired compatibility between red grouse and raptors. The quality of keeping and legal predator control is good, as is grouse health, but grouse mortality all year round is high and 78% of adult grouse found dead can be attributed to raptor predation. The evidence does not allow us to distinguish between raptor species. It has not yet proved possible to restore Langholm to a productive grouse moor with the available policy and management tools. This criterion is rated **amber** at the moment, with an end of project projection of **red/amber**, again in anticipation of a need to trial further adaptive management options.

1.7.5. Stakeholder engagement is **green** and has led to a better understanding of moorland management; how a viable game shooting enterprise underpins this moorland management; an increased acknowledgement that birds of prey are an important component of a functioning moorland ecosystem; and an improved understanding of practicable and acceptable options to resolving current management concerns.

- 1.8. The diversionary feeding of hen harriers proved to be a cost-effective, practical and viable technique for reducing predation of grouse whilst there were a maximum of three harrier nests (the first 6 years.)
- 1.9. We are not confident that the target of 1,000 brace shot can be achieved within the project timescale given current management measures. We have reasonable confidence that grouse recovery is not being restricted by habitat, but may be restricted by raptor predation of adult grouse and low grouse productivity post laying; we cannot yet determine the cause of the latter with confidence but it seems likely it is also associated with raptor predation rather than disease, inadequate food supply, weather conditions or other mortality.
- 1.10. Two large scale outbreaks of heather beetle in 2009 and 2010 have prompted the keeping team to develop novel restoration and re-seeding techniques which could be of significant help to other moors in Scotland.
- 1.11. The annual investment in keeping is £225,000. The keepers' moorland management has allowed it to meet its habitat targets and the SPA objectives, but we now need to consider new adaptive management measures to realise an economic reward in terms of grouse shooting. Until that return on investment is delivered LMDP is not providing an example of an economic model that other marginal/ recovering moors can follow.
- 1.12. The project potentially has another three years to run. The key challenge remaining is to achieve grouse recovery. We will be preparing an 'options / next steps' paper for publication in early 2015.



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